The Current State of Knowledge Concerning The Distribution of Coral in The Maritime Provinces

Cogswell, A.T., E.L.R. Kenchington, C.G. Lirette, K. MacIsaac, M.M. Best, L.I. Beazley and J. Vickers

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THE CURRENT STATE OF KNOWLEDGE CONCERNING THE DISTRIBUTION OF CORAL IN THE MARITIME PROVINCES

By

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Over the last 6 years DFO research vessel fisheries surveys, in concert with benthic research missions focussing primarily upon recently established conservation areas (Northeast Channel (NEC) Coral Conservation Area (2002), the Stone Fence *Lophelia* Conservation Area (LCA) (2004) and the Gully Marine Protected Area (2004)), have dramatically increased the number of geo-referenced records of coral within the Maritimes Region. These recent acquisitions have improved our understanding of coral distribution and ecosystems. This report provides a regional review of distribution for the 5 major orders of coral within the Maritimes Region (Alcyonacea, Antipatharia, Gorgonacea, Pennatulacea, and Scleractinia). A portion of the report is specifically dedicated to providing an overview of coral taxa described within and surrounding each conservation area. This section also utilizes recently acquired benthic survey data from 2003-2007 to: 1) describe the effectiveness of the NEC Coral Conservation Area boundaries in meeting their conservation objectives, 2) describe the preferred slope and depth preferences for coral taxa within the Gully Marine Protected Area, 3) define the known extent of *Lophelia pertusa* within the LCA and describe areas more intensely impacted by bottom fishing prior to its closure in 2004, and 4) describe the diversity within and surrounding each closure area in conjunction with an assessment of connectivity between the three areas. Finally, the report discusses how the recent influx of georeferenced coral records, and an increase in requests for coral distribution data, has stimulated the need for an effective means to manage these data. Both the structure and contents of a recently compiled coral database are described.

RÉSUMÉ

Cogswell, A.T., E.L.R. Kenchington, C.G. Lirette, K. MacIsaac, M.M. Best, L.I. Beazley and J. Vickers. 2009. The current state of knowledge concerning the distribution of coral in the Maritime Provinces. Can. Tech. Rep. Fish. Aquat. Sci. 2855: v + 66 p.

Ces six dernières années, les relevés halieutiques effectués par les navires scientifiques du MPO, ainsi que les études benthiques axées principalement sur les zones de conservation récemment créées – zone de conservation des coraux du chenal Nord-Est (NEC), créée en 2002, zone de conservation de *Lophelia* de Stone Fence (LCA), créée en 2004 et zone de protection marine du Gully, créée en 2004 – ont permis d'accroître considérablement les données géoréférencées sur les coraux dans la Région des Maritimes. Or, ces données ont amélioré notre connaissance de la répartition des coraux et des écosystèmes coralliens. Le présent rapport donne un aperçu de la répartition de cinq grands ordres de coraux dans la Région des Maritimes (*Alcyonacea*, *Antipatharia*, *Gorgonacea*, *Pennatulacea* et *Scleractinia*). Une partie du document est consacrée à un survol des taxons de coraux situés au sein et alentour de chaque zone de conservation. Cette partie met aussi à profit les données acquises dans le cadre des relevés benthiques réalisés de 2003 à 2007 pour : 1) décrire l'efficacité de la zone de conservation des coraux établie dans le chenal Nord-Est (NEC) par rapport aux objectifs de conservation visés par la création de cette zone; 2) décrire les préférences des taxons de coraux en matière de profondeur et de pente du substrat dans la zone de protection marine du Gully; 3) définir l'étendue connue de *Lophelia pertusa* au sein de sa zone de conservation (LCA) et décrire les parties de cette zone qui ont été les plus touchées par la pêche de fond avant la fermeture de la zone en 2004, et enfin 4) décrire la diversité au sein et alentour de chaque zone de conservation et évaluer la connectivité entre ces trois zones. Le document montre aussi comment l'apport récent de données géoréférencées sur les coraux et une plus grande demande de données sur la répartition des coraux ont accru la nécessité d'un outil efficace pour gérer ces données. Enfin, le document décrit également la structure et le contenu d'une base de données sur les coraux récemment créée.

INTRODUCTION

The earliest confirmed report of cold-water corals (hereafter referred to as ‘coral’) in the Maritimes Region was of *Paragorgia arborea* found in deep water at the mouth of the Bay of Fundy by A.E. Verrill prior to 1864 (Whiteaves 1901), and one of the earliest maps of coral distribution was produced by Goode (1887), largely using local fishermen’s knowledge (Figure 1). After a gap of nearly 100 years, there has been a renewal of research on the distribution of corals off of Nova Scotia which has increased our knowledge of their distribution and biology (Breeze *et al.* 1997; MacIsaac *et al.* 2001; Gass 2002; Mortensen *et al.* 2006; Gordon and Kenchington 2007). In particular, during 2001-2003, a large amount of new data on cold-water corals in Atlantic Canada was collected and analyzed through a DFO research program established with funding from the Environmental Studies Research Funds (ESRF) (Mortensen *et al.* 2006; Gordon and Kenchington 2007). Data sources for these more recent studies included DFO groundfish trawl survey bycatch, the commercial bycatch obtained through the DFO Fisheries Observer Program, interviews with fishers and targeted benthic surveys using non-destructive sampling equipment (i.e., remotely operated vehicles equipped with cameras).

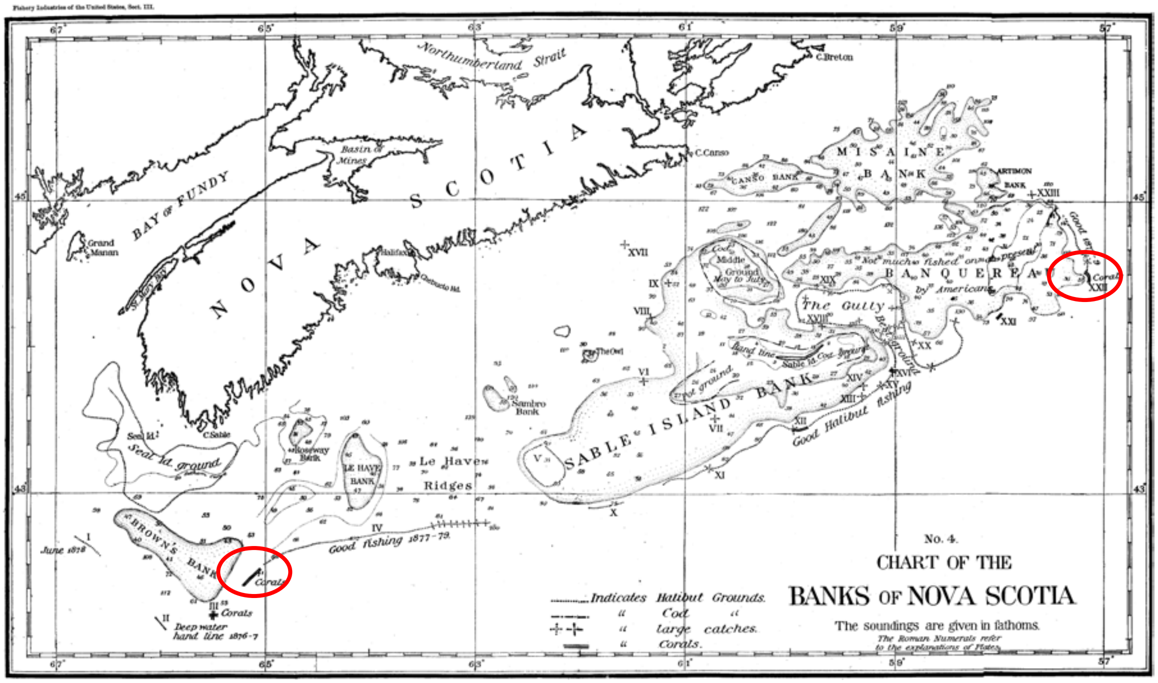


Figure 1. Chart describing early accounts of coral distribution (circled) in relation to “good fishing” on the Scotian Shelf (Goode 1887).

Together, this research has provided data on the distribution of coral and its vulnerability to fishing gear which are required to create protected areas. There are now two coral conservation areas on the Scotian Shelf (Figure 2 - Northeast Channel Coral Conservation Area (NEC CCA) and the Stone Fence *Lophelia* Coral Conservation Areas (LCA)), and corals are further protected in the Gully Marine Protected Area (Gully MPA) (Figure 2), the largest submarine canyon on the Northeast Atlantic slope. It is interesting to note that the original coral beds mapped in the 19th century remain important coral habitat today, and are the site of the two coral conservation areas.

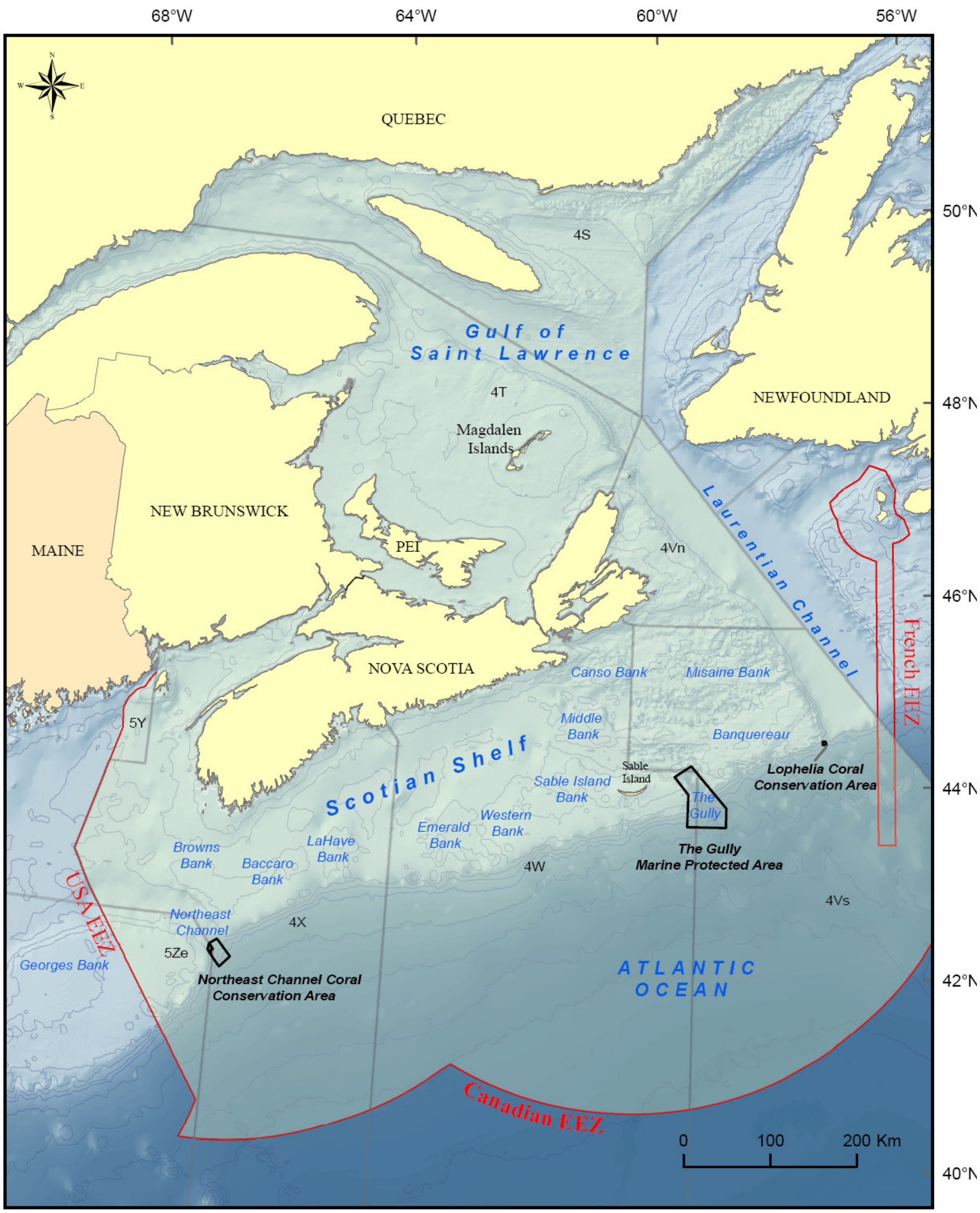


Figure 2. Conservation zones (highlighted in black) with restricted or limited fishing along the Scotian Slope. The green shaded area illustrates the primary area covered in this report. The red line indicates the exclusive economic zones of Canada, France and the United States of America.

Since the publication of the review by Gordon and Kenchington (2007), data on corals from scientific research missions through to 2008 have been processed (Table 1 & Figure 3). These data significantly increase our knowledge of the distribution of these taxa as they include two ROPOS (Remotely Operated Platform for Ocean Science) missions and one DSIS (Deep Seabed Intervention System) mission to depths of 2500 m (conducted in 2006 and 2007), as well as two missions using the DFO Campod, a remotely operated camera on an aluminum tripod frame, in 2005 and 2008 (Kenchington 2007, 2008). Data was also obtained from three canyons which had not previously been sampled in detail: Logan, Shortland and Haldimand canyons, which were targeted in 2006 and 2008.

Table 1. Data sources included in this report and not previously documented elsewhere. Survey locations for the ROPOS, DSIS and Campod missions are illustrated in Figure 3.

Data Source	Type of Sampling	General Area	Year
ROPOS	Video/Images/Collections	Northeast Channel, Jordan Basin	2006
ROPOS	Video/Images/Collections	Gully MPA, Stone Fence	2007
DSIS	Video/Images/Collections	Logan Canyon, Gully MPA	2006
Campod	Video/Images	Northeast Channel, Jordan Basin	2005
Campod	Video/Images	Gully MPA, Shortland and Haldimand Canyons	2008
DFO Research Vessel Surveys (R/V)	Bycatch	Scotian Shelf and Slope	2003-2007
DFO R/V	Bycatch	Gulf of St. Lawrence	2002-2009
Fisheries Observer Program (FOP)	Bycatch	Scotian Shelf and Slope	2003-2007

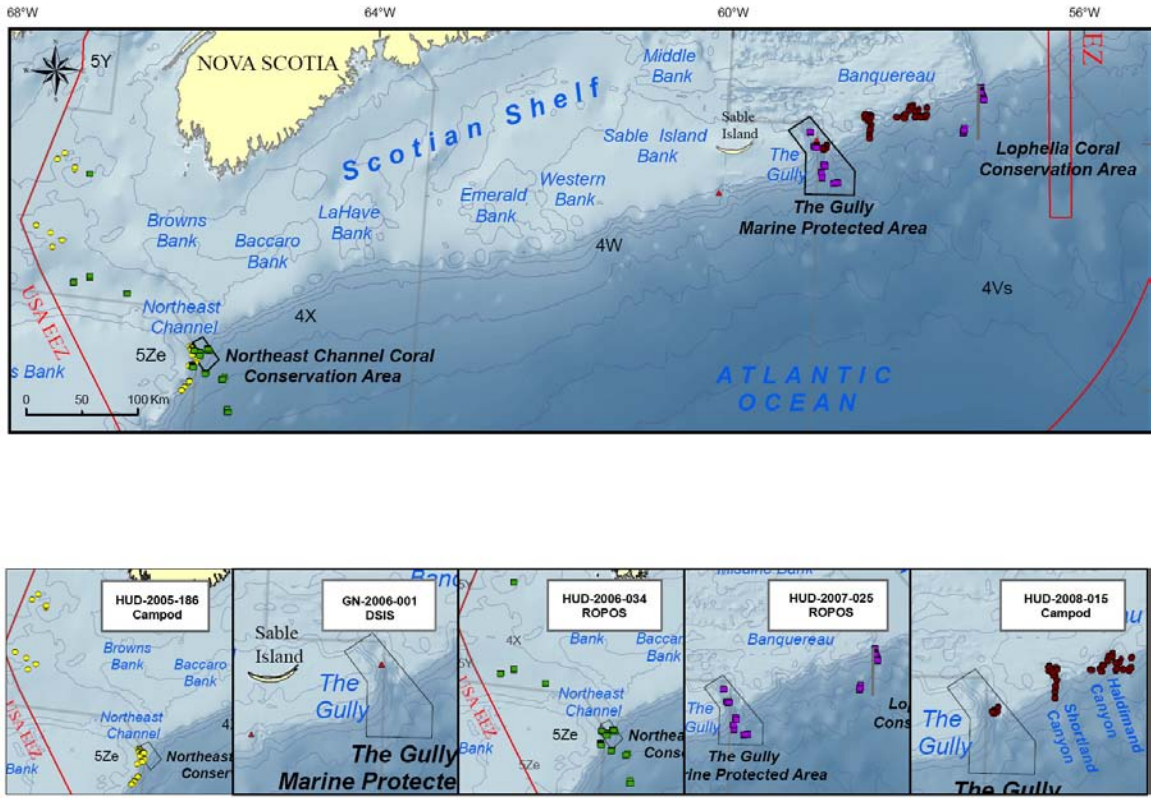


Figure 3. Locations of the scientific sampling (ROPOS, DSIS, Campod) conducted between 2003 and 2008 on the Scotian Shelf and Slope (see Table 1).

Here we present the updated range maps for coral off of Nova Scotia, including the new data collected from missions summarized in Table 1 as well as previously existing data summarized by Gordon and Kenchington (2007). The area of coverage is illustrated in Figure 2. Included are research vessel groundfish trawl bycatch data from the Gulf of St. Lawrence which were recently identified (Ferguson 2008; Levesque *et al.* 2008). A report on coral distribution in the Newfoundland region has been produced, complementing this report to provide an Atlantic Canada perspective (Wareham and Edinger 2005).

In compiling our report we took the opportunity expand upon and refine an existing database initially created by Dr. Donald C. Gordon and later maintained by Mrs. Cynthia Bourbonnais, housing all of the coral records from the above named sources from Atlantic Canada. This involved reviewing and editing previous records and standardizing the taxonomic nomenclature used to identify the corals. All data points are geo-referenced, thus enabling export to geographic information systems (GIS) for mapping and integrating with other data layers. We provide a description of this database at the conclusion of the report.

Regional Distribution Maps

The term "coral" has been used to describe several different orders within the phylum Cnidaria and the subphylum Anthozoa. However, the higher level taxonomy of the anthozoans is not universally recognized. In the coral database, where available, taxonomic names follow the "Integrated Taxonomic Information System" (ITIS-www.itis.gov). If the taxon is not currently entered into ITIS then the "European Register of Marine Species" is taken as the second authority (ERMS - www.marbef.org). In instances where neither ITIS nor ERMS contains classification information for the taxon in question, the literature serves as the third and final authority. For this report, ERMS orders are used to describe coral taxa. This is not the classification scheme accepted by most cnidarian taxonomists. In ITIS, Alcyonacea (Soft Corals) and Gorgonacea (Branching Corals) are combined into the same order Alcyonacea. ERMS separates the two orders following the system applied most commonly over years past. Given the distinct morphological differences and tendency to select for different substrate types between the two orders (Alcyonacea – flat bottoms, Gorgonacea – topographically diverse terrain with high slope), the ERMS classification scheme makes the most sense for assessing distribution and vulnerability to fishing pressures.

Regional distribution maps were produced for each coral order and their component taxa. Underwater photos of each taxon are illustrated where available: Alcyonacea (Figures 4-6), Antipatharia (Figures 7&8), Gorgonacea (Figures 9-11), Pennatulacea (Figures 12-14) and Scleractinia (Figures 15-17).

Data Notes

While the following maps represent the current state of knowledge concerning coral distribution in the Maritimes Region, the known extent and quantity of a taxa is largely a function sampling bias. For example, the known distribution for Antipatharia (Figure 7) stretches into some of the deepest benthos (~2500 m) ever visually captured in the Maritimes Region. The sampling effort in deep water at the base of the Scotian Slope is prohibited by the costs and availability associated with gear necessary to sample this area. Another example of bias is illustrated by the solitary cup coral *Flabellum alabastrum*. Prior to the Hudson 2008-015 mission there were less than 500 records of *F. alabastrum* in the Maritimes Region (Kenchington 2008). A high concentration of this species discovered in Shortland Canyon during this mission increased the number of records to nearly 35,000!

While the coral bycatch data from the randomly stratified sampling efforts of the DFO fisheries surveys represents the largest spatial extent of any data source from the proceeding maps, they contribute less than 2% of the total coral records in the Maritimes Region. Benthic research surveys from 2005-2008 have focused mostly on protected areas so that researchers can provide the best advice to those responsible for managing these areas. Video and still image analysis from Campod/ROPOS missions in 2005, 2006, 2007 and 2008 captured a great amount of data but covered a relatively small footprint (Jordon's Basin, Northeast Channel Coral Conservation Area, Gully Marine Protected Area, Stone Fence *Lophelia* Conservation Zone, Haldimand and Shortland Canyon). In fact these 4 missions currently represent ~91% of all the geo-referenced coral records in the Maritimes Region.

What these examples of uneven sampling effort illustrate is that areas not sampled are not equivalent to null records. Rather, they represent data gaps and require further sampling to confirm or deny the presence of coral. Understanding the spatial limitations and quality of coral distribution data in the Maritimes will be essential for making good marine spatial decisions. Making assumptions about a location with good data coverage but poor data quality (e.g., Traditional Ecological Knowledge) can be just as misleading as over-interpreting large areas based on high quality data with limited spatial coverage (e.g., ROPOS missions).

Taxonomic Nomenclature

Many of the following regional distribution maps contain taxonomic nomenclature that requires further explanation. The taxonomic level to which each record can be identified is dependent on the expertise and resources available to the person making the ID. This is especially true of Fisheries Observer Reports where the variability of the taxonomic identification is a function of both training and experience. For example, a sea pen recorded by an Observer may only be identifiable to the order Pennatulacea, whereas visual examination by a taxonomist may further classify the taxa to species (e.g., *Pennatula borealis*). The same is true for video and still image analysis. The classification level given coral records from video analysis is only as refined as the video quality will allow. When analyzing video collected when the forward velocity of the vehicle is slow enough, the altitude and lighting are optimized, there is little particulate in the water column, and the taxa being described is large enough; taxonomic identifications can be made to the species level. Even if video quality is of a high standard, the resolution of that video may preclude the species level identification of smaller or juvenile fauna. In this case, perhaps identifications could be taken only to the genus level or in some cases where video quality is especially poor, the order, class or subphylum. While video analysis was given as an example, taxonomic classification varies widely within each sampling method and between sampling methods.

When classification of taxa is uncertain by any method, a precautionary approach is taken. If the genus is certain to the recorder and only one species of that genus is present in the sampling area, then the abbreviation sp. follows the genera (e.g., *Primnoa* sp.). If the genera is certain to the recorder but more than one species is thought to be represented during transects in the sampling area, then the abbreviation spp. follows the genera (*Pennatula* spp.). Where recorders can only identify to family, then this name is used to identify the taxa, followed by an F. to denote family (e.g., Nephtheidae F.). The same is true when classifying to order or phylum (e.g., Pennatulacea O.). As taxonomic identifications become more certain for a survey or geographic area, usually via taxonomic verification of sample vouchers, nomenclature is adjusted within the database to reflect this. Thus, the following maps reflect a snapshot of the database and will change as taxonomic classification accuracy continues to evolve.

The following maps are organized to show the distribution by each of the five coral orders most common in the Maritimes Region. These orders fall within the phylum Cnidaria, the class Anthozoa and 3 subclasses: Hexacorallia (order Scleractinia), Ceriantipatharia (order Antipatharia) and Octocorallia (orders Alcyonacea, Gorgonacea and Pennatulacea). Maps representing the distribution of each order are further broken down into maps for families within that order. Within each of these family maps, taxa to the lowest possible classification are plotted.

New Records

In recent years, intense sight specific sampling efforts by DFO benthic surveys have brought to light new or unconfirmed taxa for the Maritimes Region, Canada and possibly science. In fact, since 2005 ~15 coral taxa have been recovered and confirmed as either: **1.** The first geo-referenced records for these taxa in the Maritimes Region (**Alcyonacea** - *Chrysogorgia agassizii*; **Pennatulacea** - *Anthoptilum grandiflorum, A. murrayi, Halipteris finmarchica, Funiculina* sp., *Kophobelemonon stelliferum,* and *Ombellula* spp.; **Scleractinia** - *Desmophyllum* spp. and *Javania* sp.), **2.** New records for the Maritimes (**Antipatharia** – *Stauropathes arctica*) or, **3.** Records either new to Canada or possibly science (**Antipatharia** – *Bathypathes patula,* c.f. *Parantipathes* sp. (new to science), *Stichopathes* spp.; **Gorgonacea** – *Paragorgia johnsoni*). The process of identifying and confirming these coral records continues as this report is written. The combination of intense sampling effort, advances in genetic sampling techniques and traditional taxonomy will enhance our understanding of coral adaptation to local environments (e.g., *Anthomastus grandiflorus* – Figure 6) while simultaneously increasing the number of described coral taxa within the Maritimes Region of Canada.

Alcyonacea (Soft Corals, Mushroom Corals)

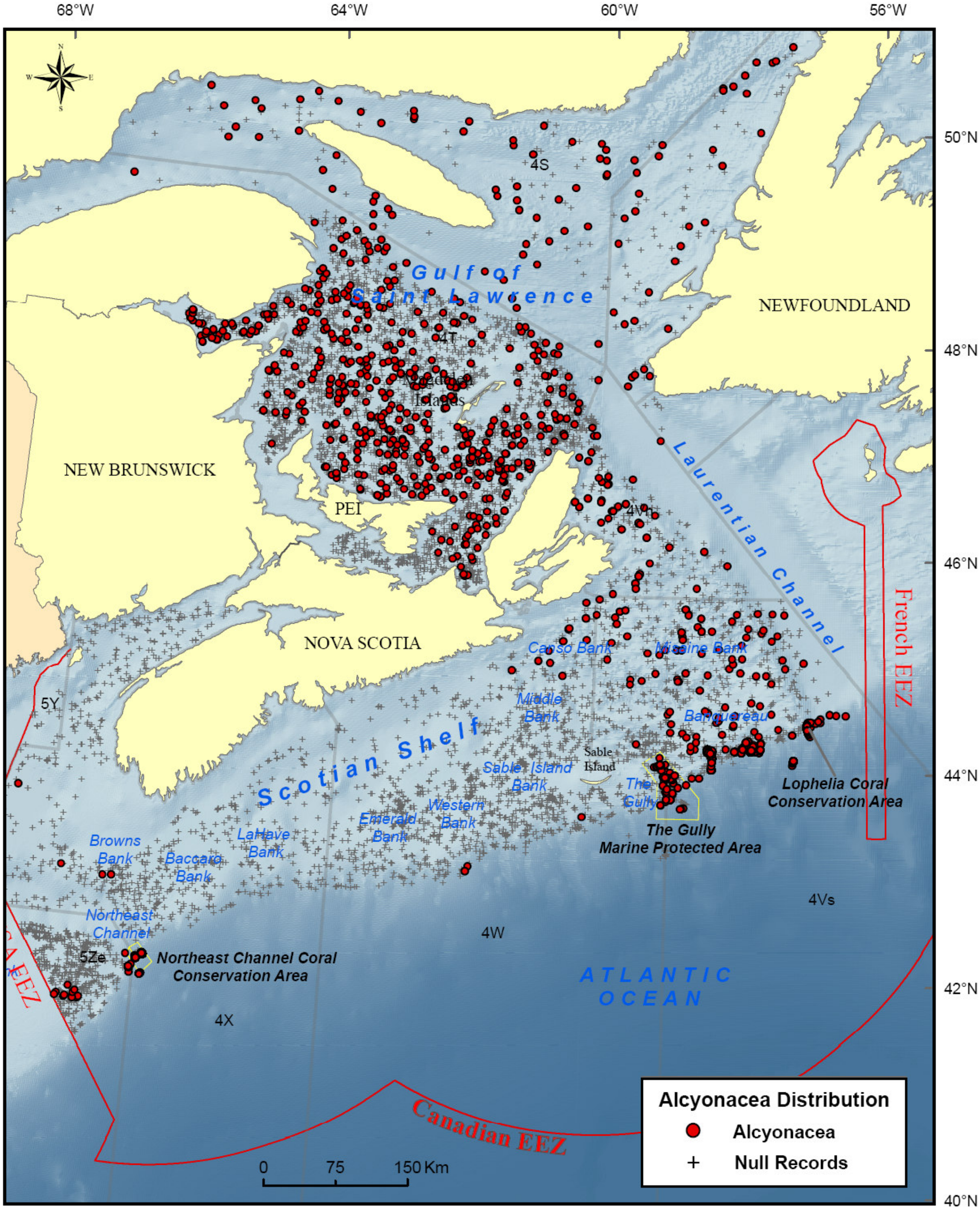


Figure 4. Distribution of soft corals (Alcyonacea). The null records come from research vessel trawls where no Alcyonacea bycatch was observed.

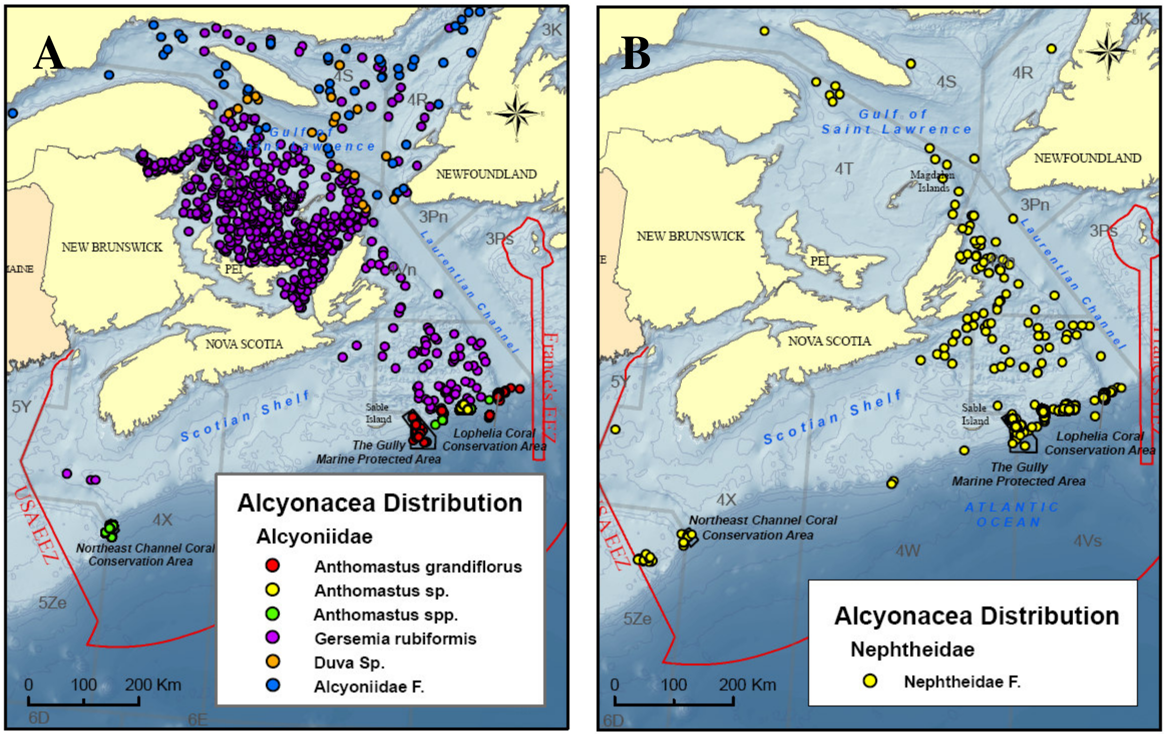


Figure 5. **A** - Records of Alcyoniidae (*Gersemia rubiformis* and *Anthomastus* spp.), and **B** - family Nephtheidae (*Drifa* sp. and other unidentifiable soft corals).

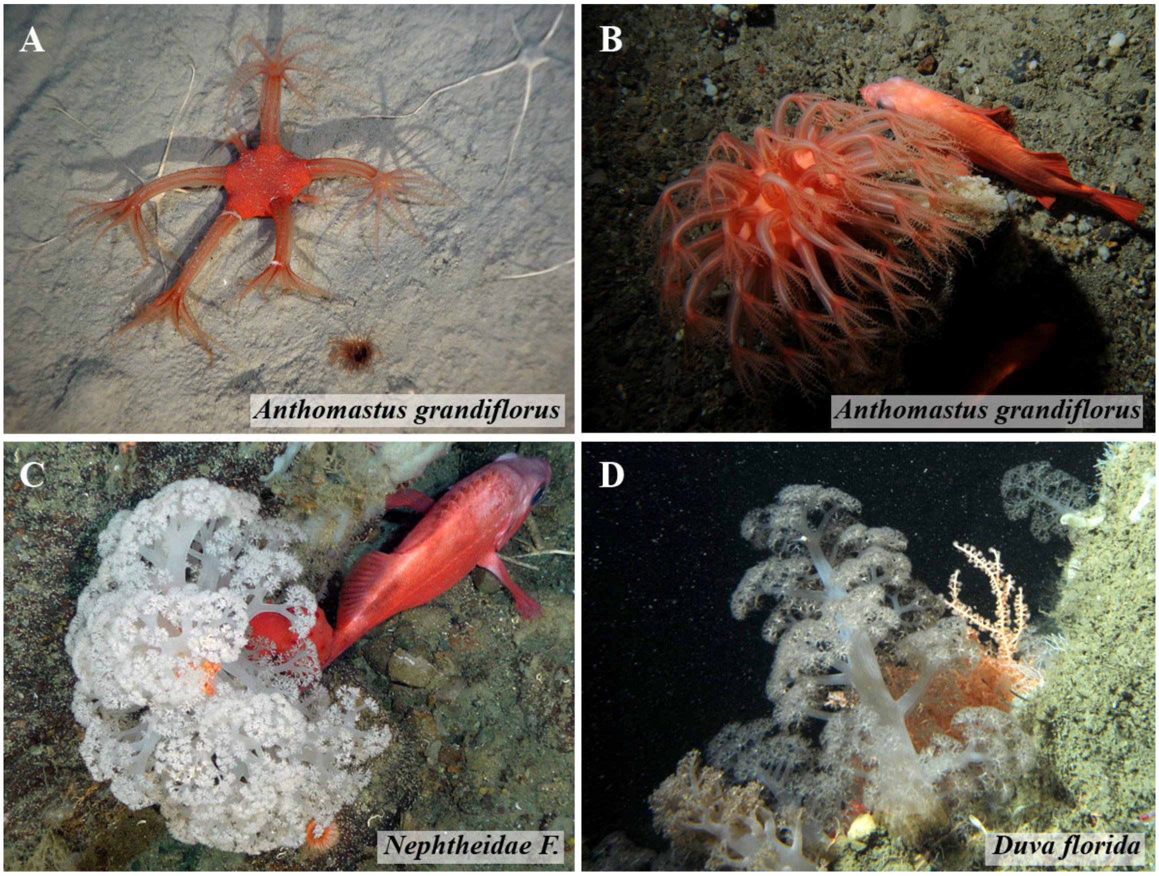


Figure 6. **A & B** – represent 2 variants of the same species which are associated with habitat type (**A** - muddy flat bottoms & **B** – pebbles, boulders and cliffs). **C** – White and grey members of the Nephtheidae family are difficult to identify by video analysis and thus are rarely assigned a definitive species name. **D** – *Duva florida* – also difficult to assign a species name when viewed from a distance, but this orientation allows for easy identification.

Antipatharia (Black Corals)

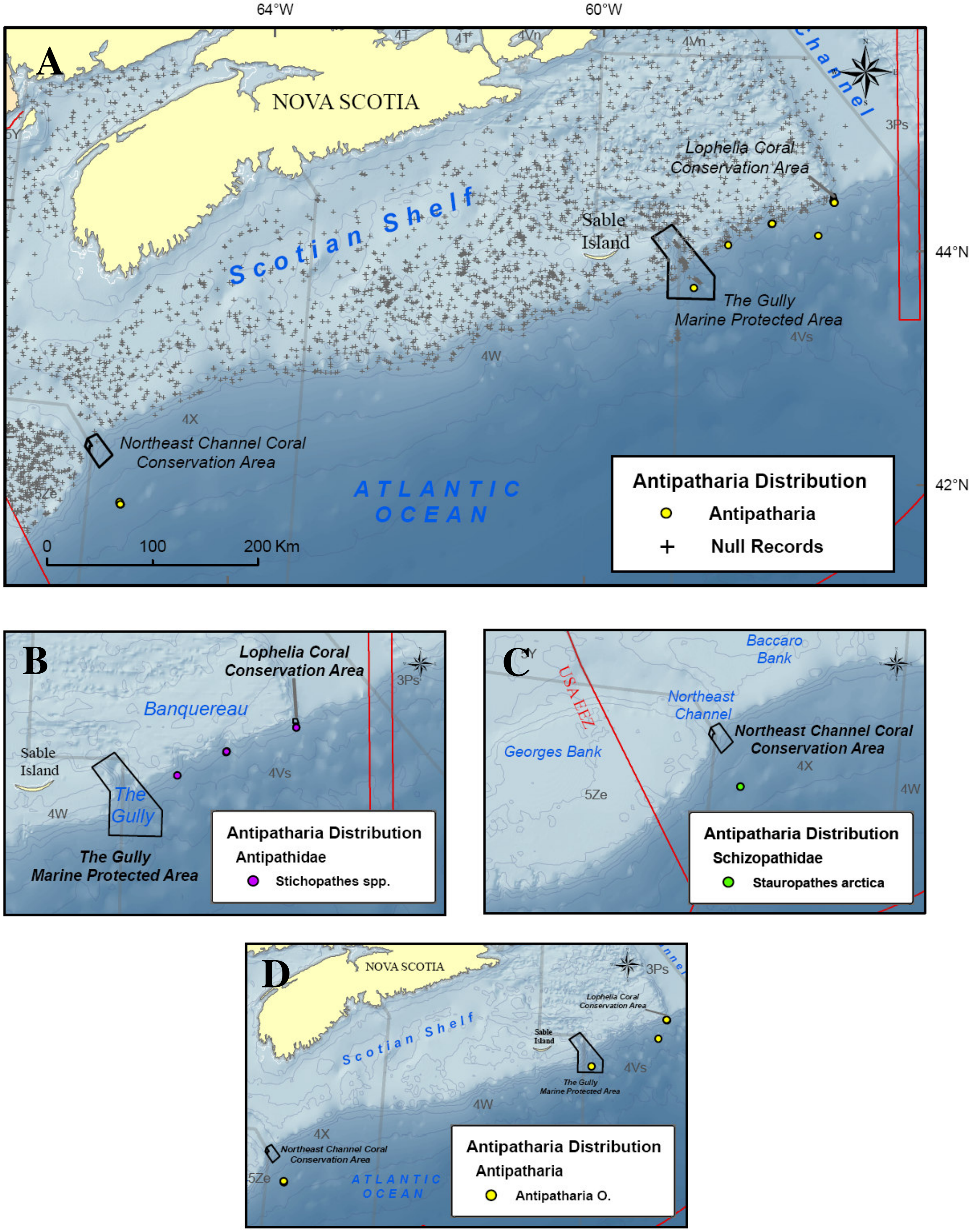


Figure 7. **A** - The distribution of black/thorny corals (order Antipatharia). With only 21 total records, this order of corals is by far the rarest found in the Maritimes Region. **B&C** - Distribution of *Stichopathes* sp. and *Stauropathes* sp. **D** - Distribution of unidentified or recently confirmed species of the order Antipatharia.

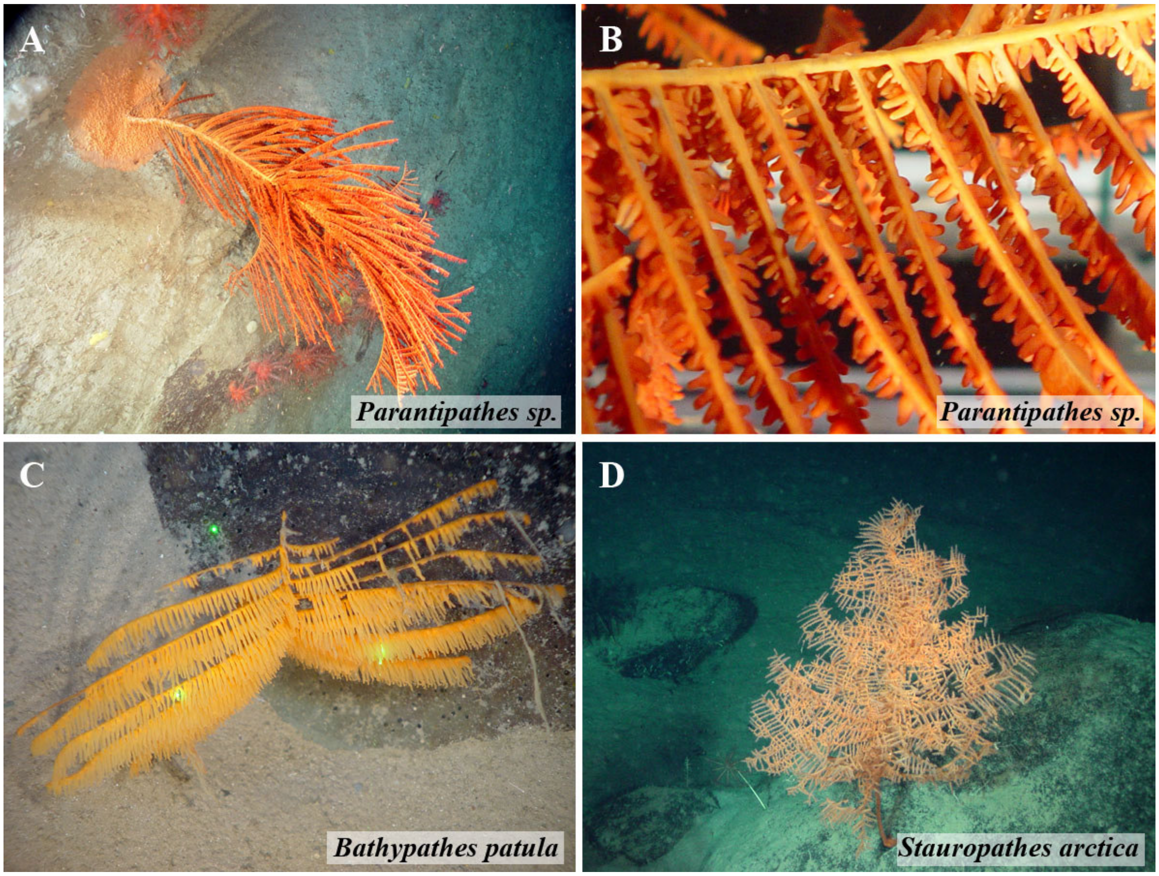


Figure 8. **A&B** – (c.f.) Parantipathes sp., possibly a new species of large black coral recently observed in the Maritimes Region during the 2007 ROPOS mission on a sheer cliff face. **C** – *Bathypathes patula* from the Northeast Channel. **D** – *Stauropathes arctica* from the Northeast Channel Coral Conservation Area collected during the 2006 ROPOS mission. The green laser points in **C** represent a distance of ~10 cm.

Gorgonacea (Branching Corals, "Trees")

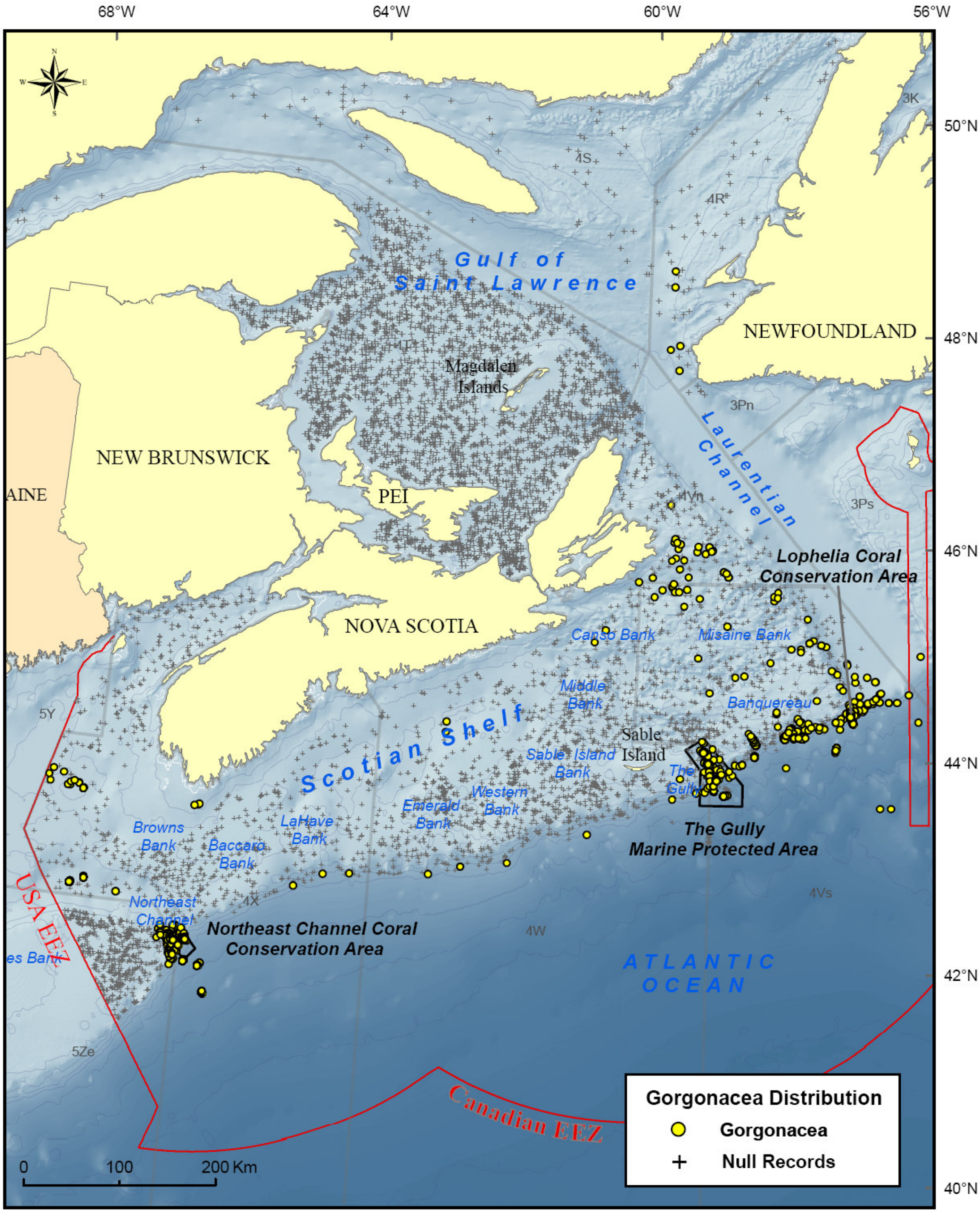


Figure 9. The Maritime distribution of branching corals (order Gorgonacea). This order contains some of the largest and longest lived invertebrate species known to science. These structure forming organisms have garnered much attention in recent years and were the impetus for establishing the Northeast Channel Coral Conservation Area.

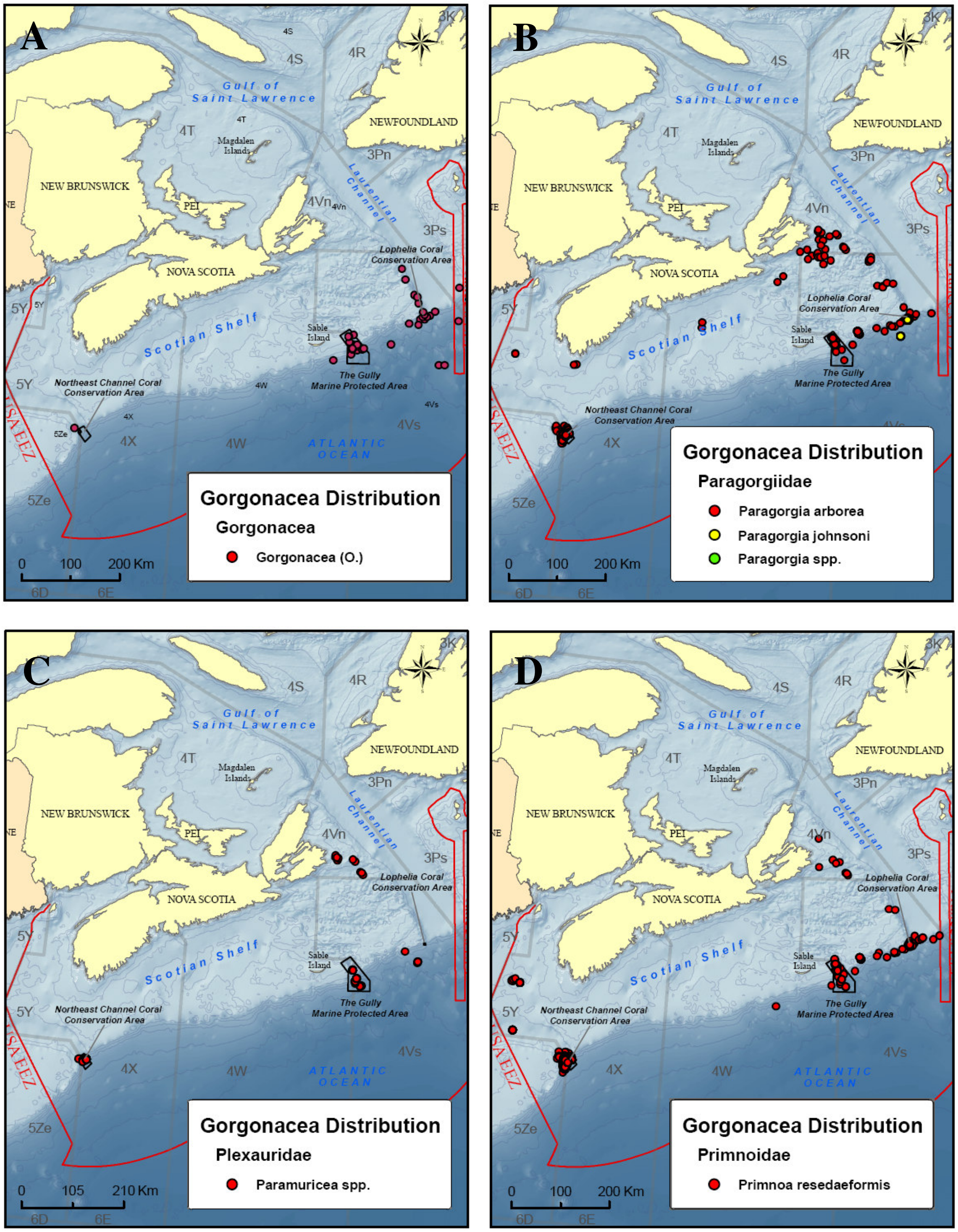


Figure 10. Maps for the 7 families of the order Gorgonacea present in the Maritimes Region. **A** – Distribution of unidentifiable families within the order Gorgonacea. **B** - Family Paragorgiidae which for our region currently contains two species: *Paragorgia arborea* and *P. johnsoni*. **C** – Family Plexauridae which includes at least one species of the large branching coral *Paramuricea* spp. **D** – Family Primnoidae represented by the species *Primnoa resedaeformis*.

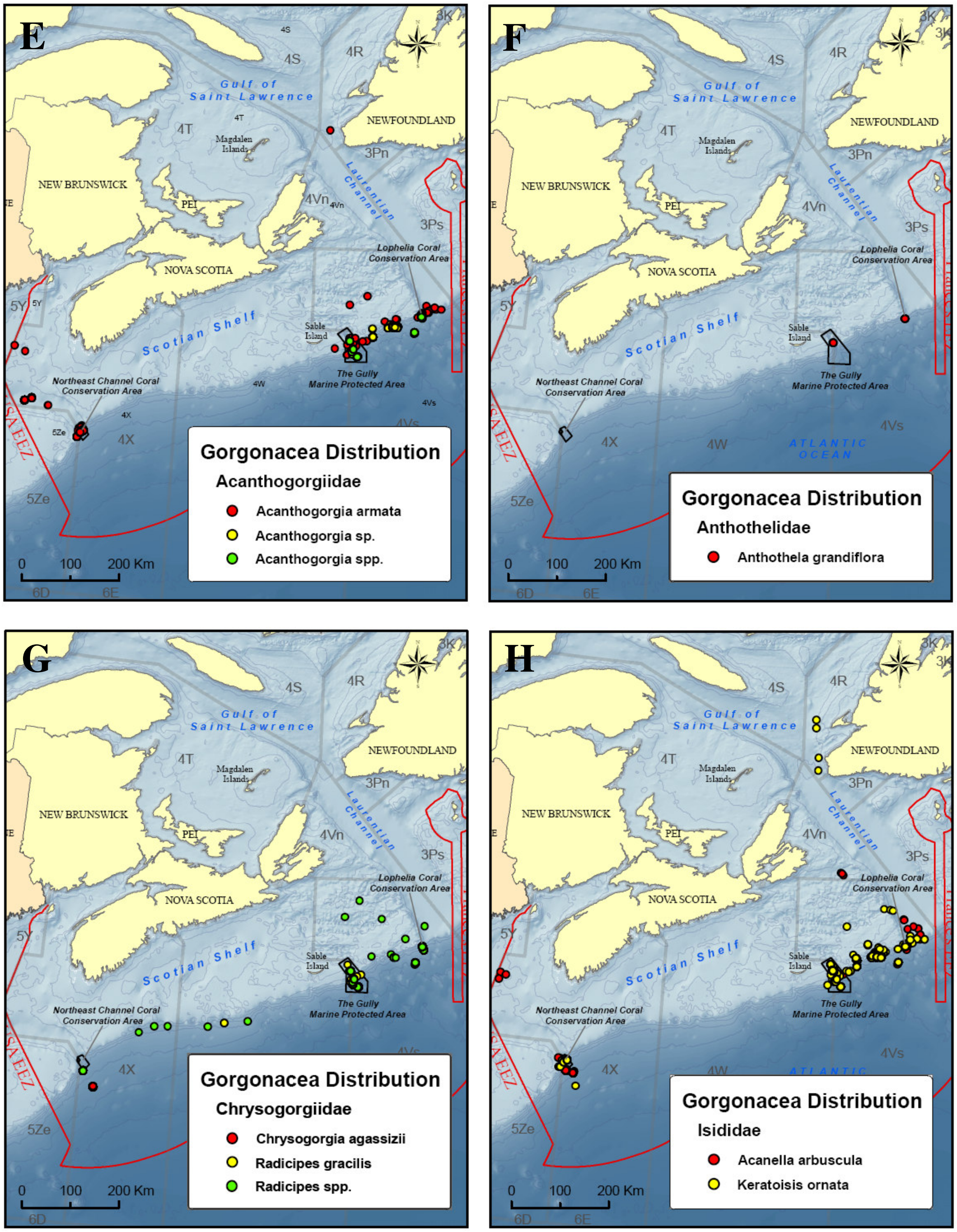


Figure 10 cont'd. Maps for the 7 families of the order Gorgonacea present in the Maritimes Region. **E –** Family Acanthogorgiidae represented by *Acanthogorgia armata.* **F –** Family Anthothelidae represented by *Athothela grandiflora*. **G –** Family Chrysogorgiidae represented by *Chrysogorgia agassizii* and *Radicipes gracilis.* **H –** Family Isididae represented by *Acanella arbuscula* and *Keratoisis ornata*.

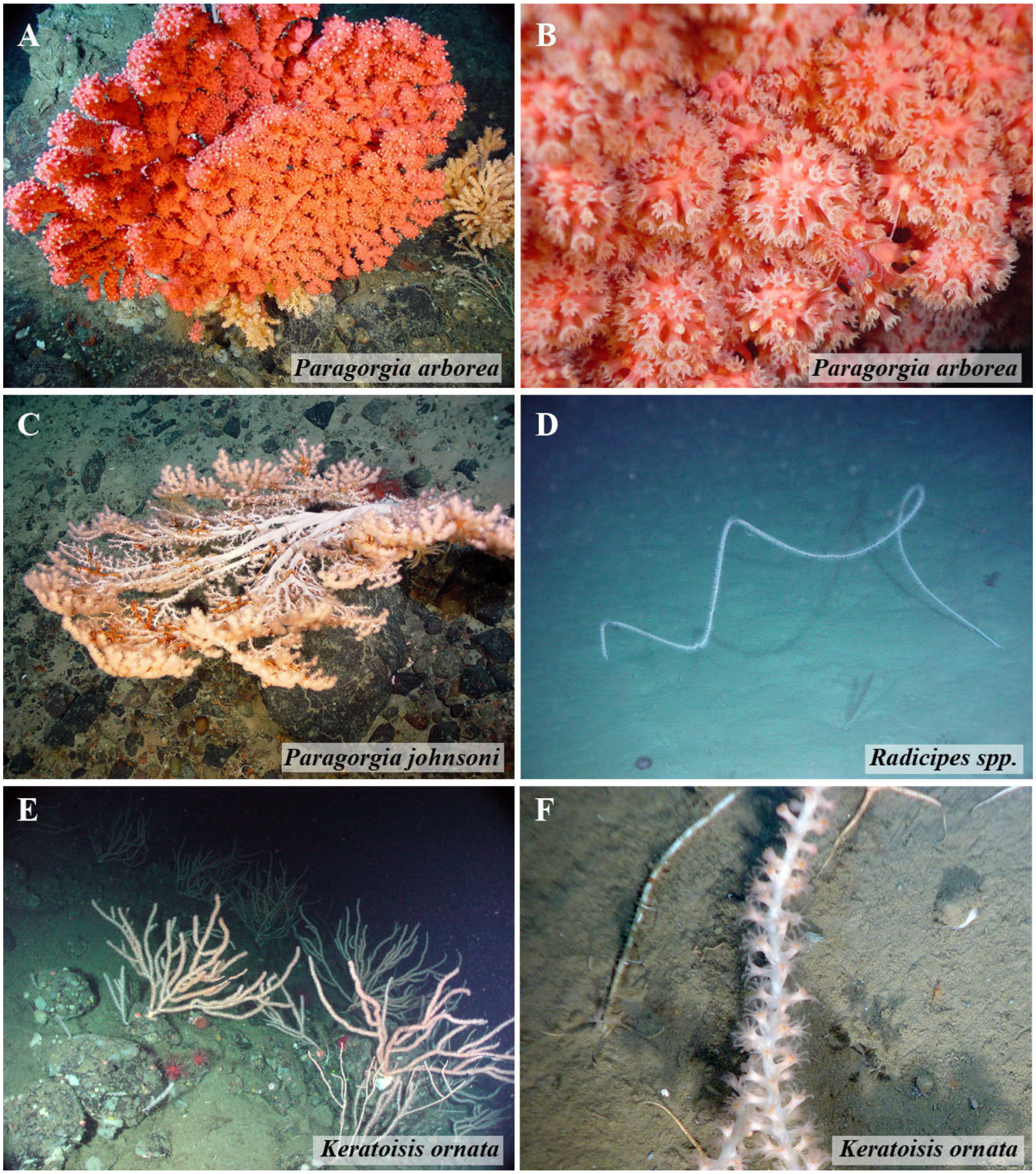


Figure 11. Representatives from the 7 families within the order Gorgonacea (**A, B & C** – Paragorgiidae; **D** – Chrysogorgiidae; **E & F** – Isididae).

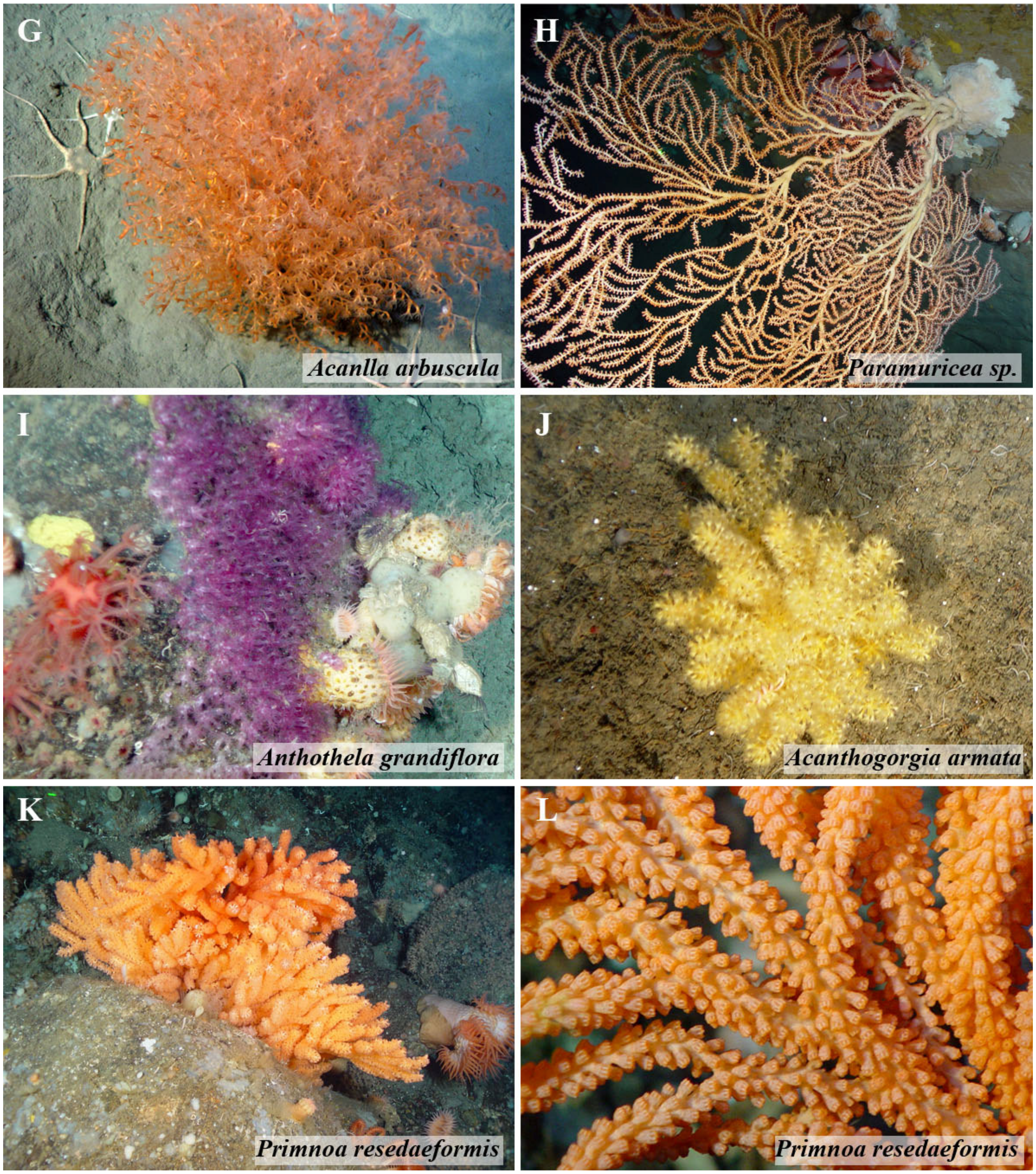


Figure 11 cont'd. Representatives from the 7 families within the order Gorgonacea (**G –** Isididae; **H –** Plexauridae; **I –** Anthothelidae; **J –** Acanthogorgiidae; **K & L –** Primnoidae).

Pennatulacea (Sea pens)

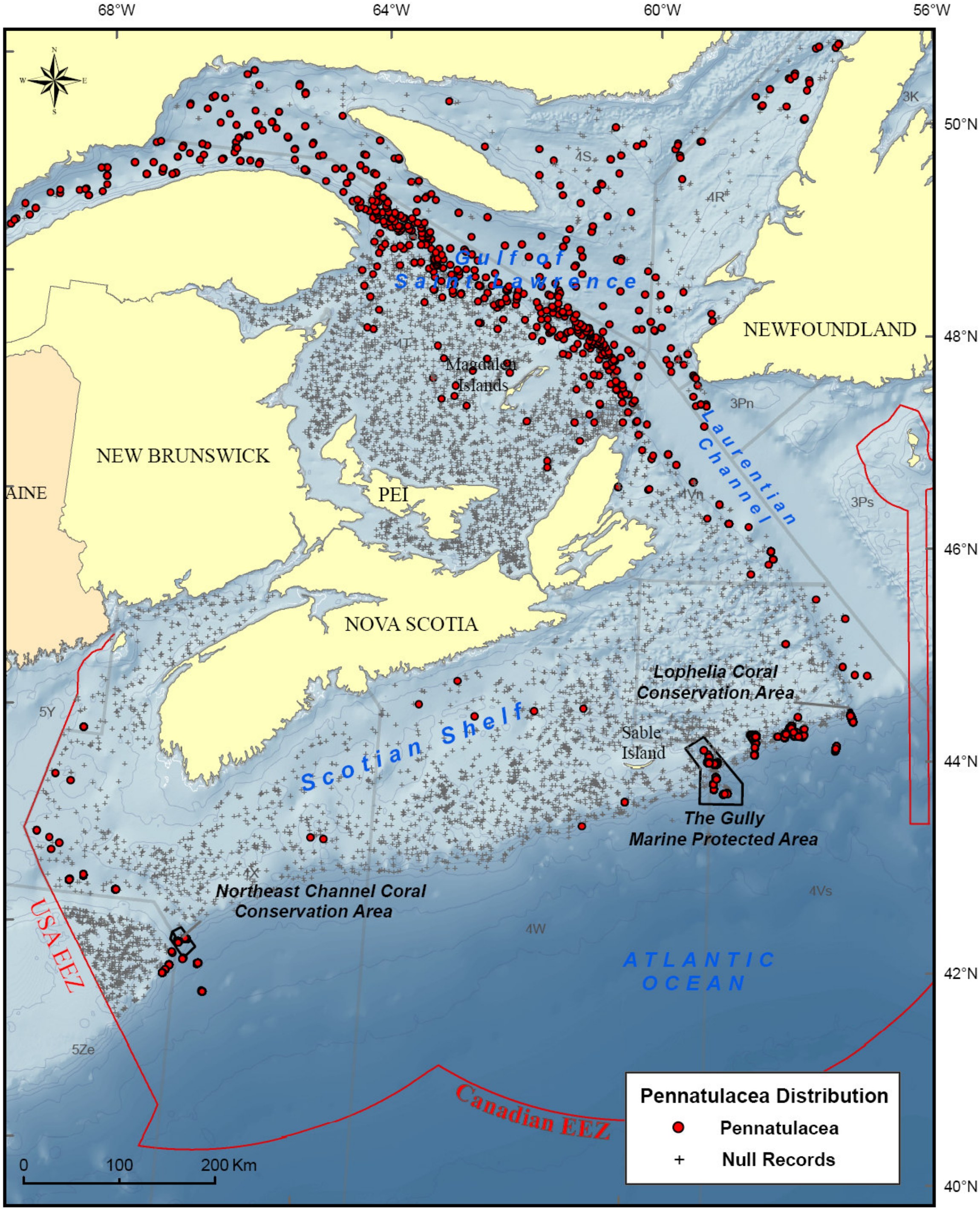


Figure 12. The Maritime distribution of sea pens (Pennatulacea). Tight aggregations or sea pen "fields" have been noted in various parts of the Maritimes Region, particularly along the Laurentian Channel.

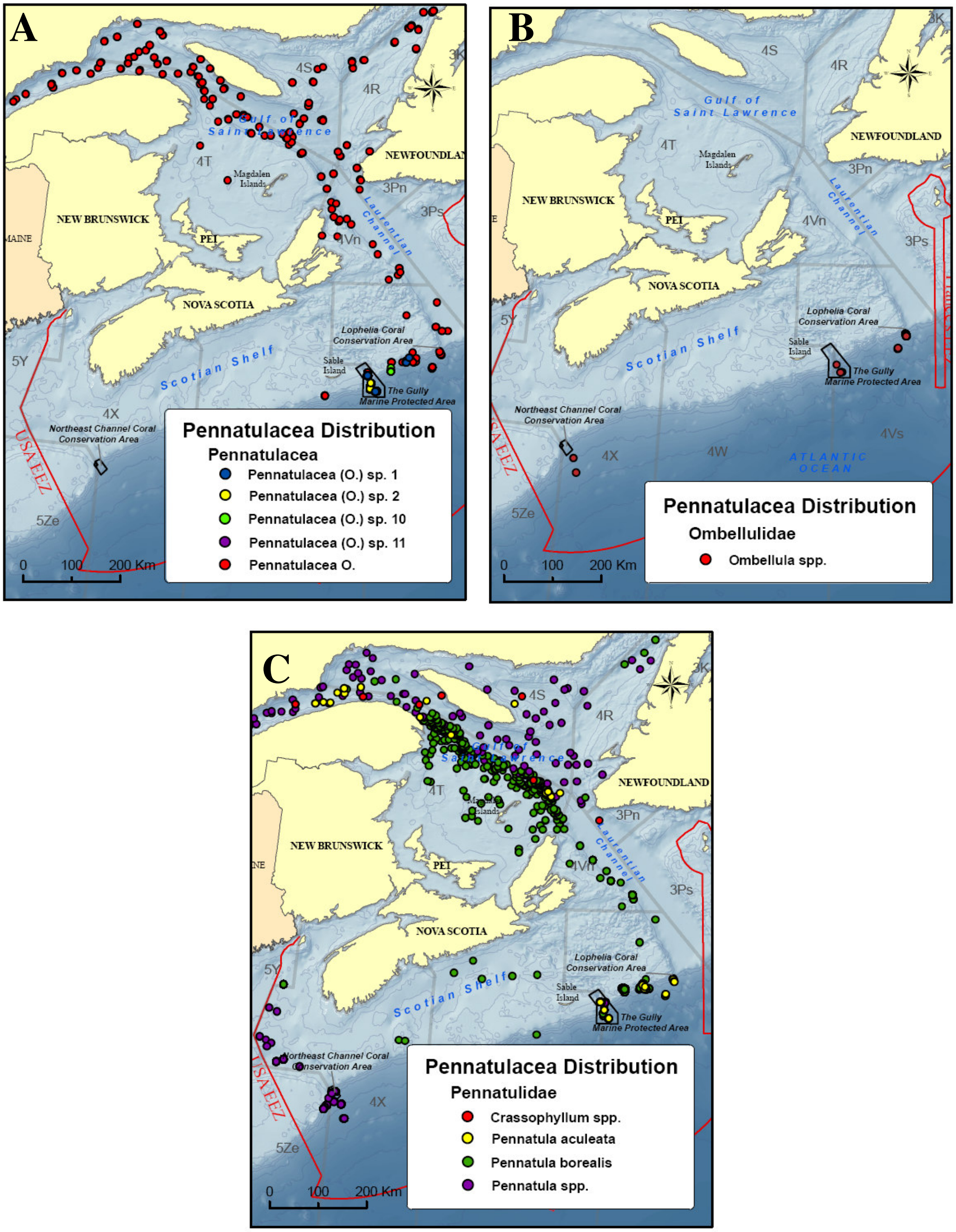


Figure 13. Maps for the 6 families of the order Pennatulacea. **A** - Yet to be identified sea pen records. **B** – Family Ombellulidae represented by the genus *Ombellula* spp. **C** – Family Pennatulidae represented by *Crassophyllum* spp., *Pennatula aculeata,* and *P. borealis.*

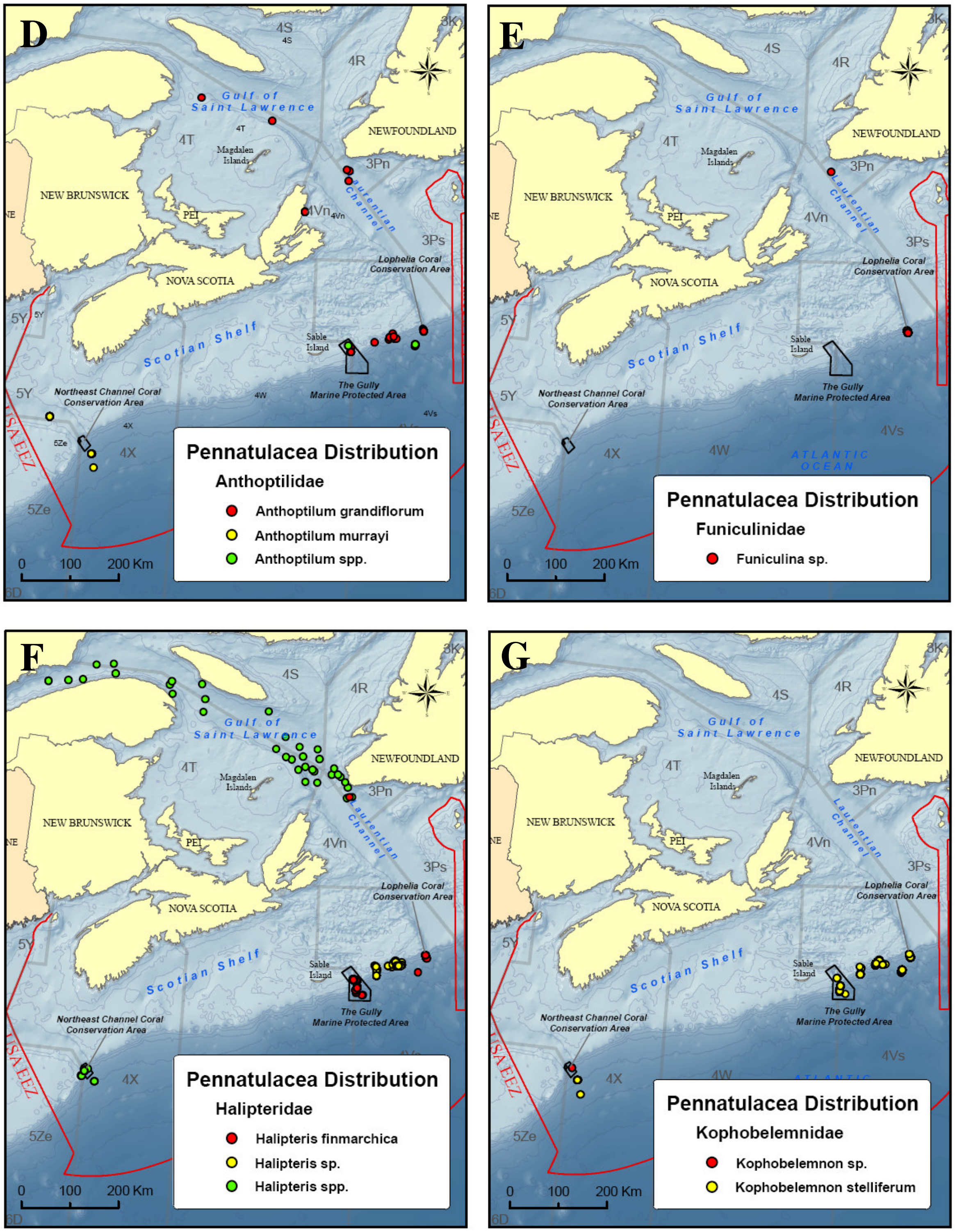


Figure 13 cont'd. Maps for the 6 families of the order Pennatulacea present in the Maritimes Region. **D –** Family Anthoptilidae represented by *Anthoptilum grandiflorum,* and *A. murrayi*. **E –** Family Funiculinidae represented by *Funiculina spp.* **F –** Family Halipteridae represented by *Halipteris finmarchica*. **G –** Family Kophobelemnidae represented by *Kophobelemnon stelliferum*.

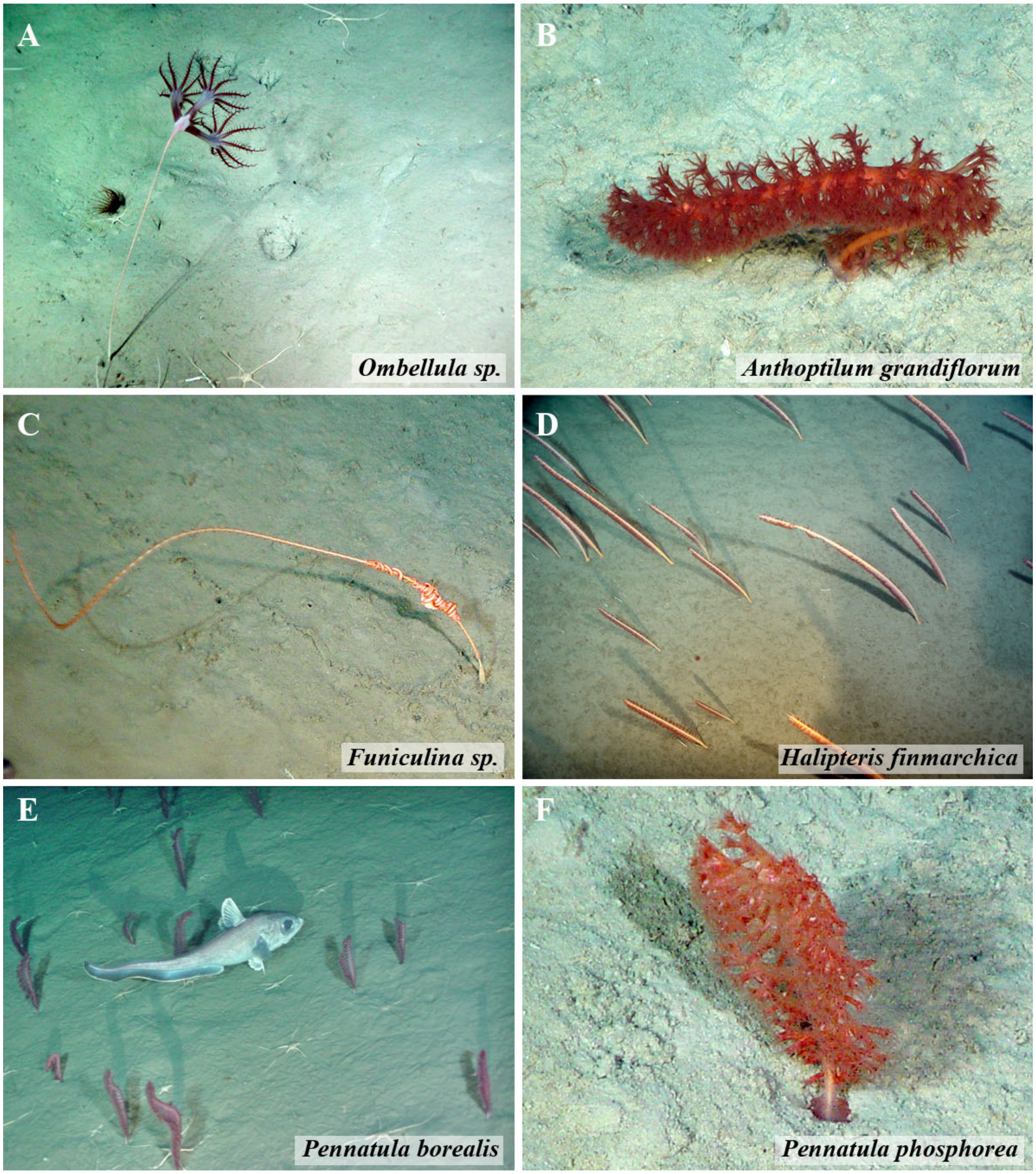


Figure 14. Representatives from 5 of the 6 families within the order Pennatulacea present in the Maritimes (**A** – Ombellulidae, **B** – Anthoptilidae, **C** – Funiculinidae, **D** – Halipteridae, **E & F** - Pennatulidae). The only family without a representative photo is Kophobelemnidae.

Scleractinia (Stony Corals, "Spider Hazards", Cup Corals)

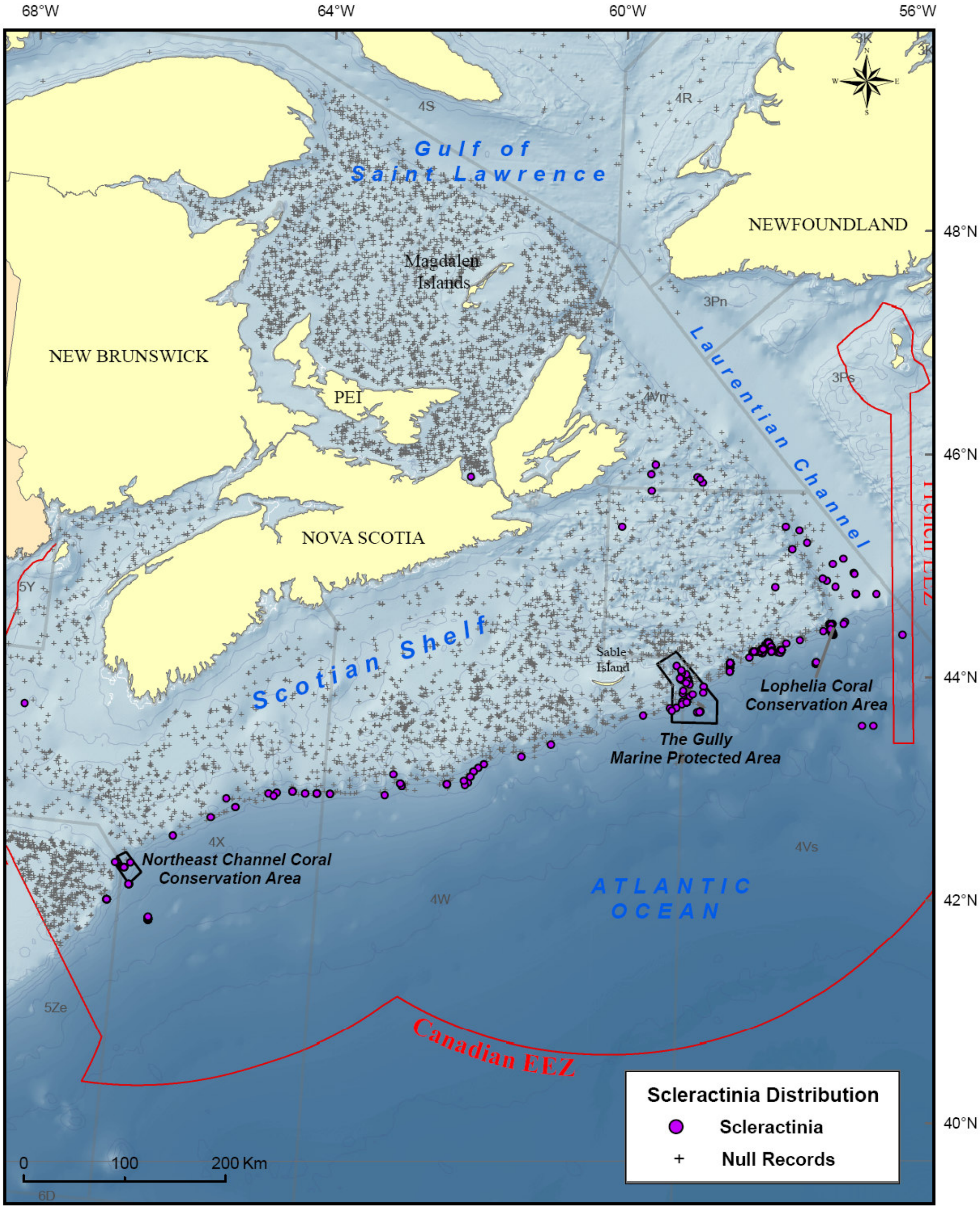
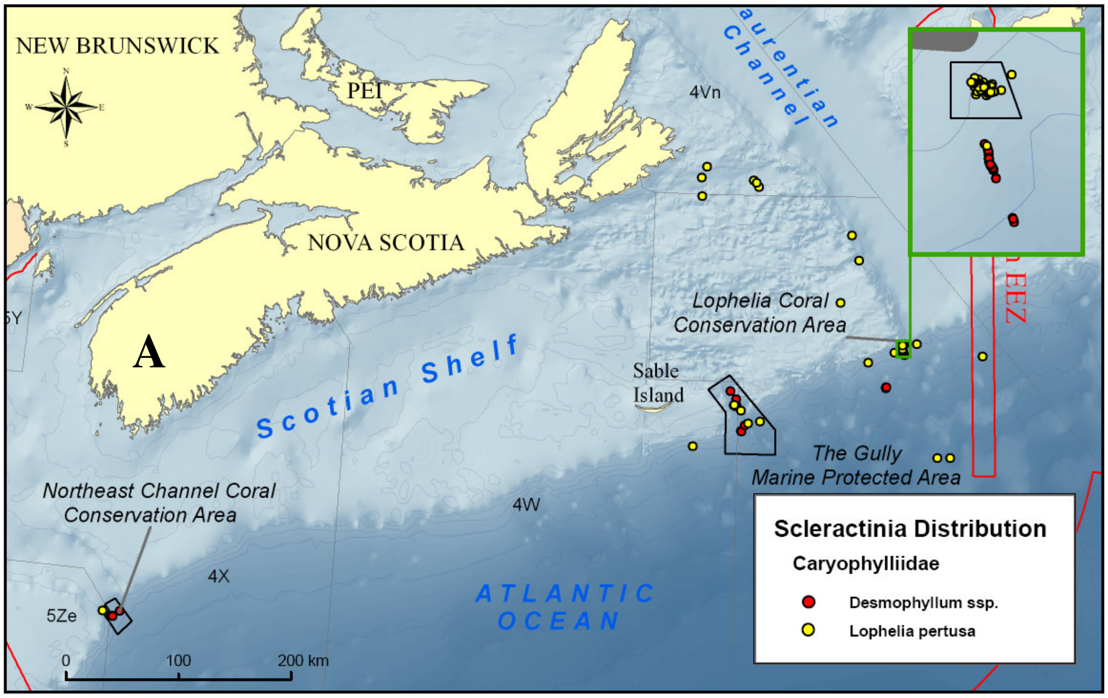


Figure 15. The Maritime distribution of stony coral (Scleractinia). This order represents nearly 36% of the total coral records for the 5 coral orders represented in this report.



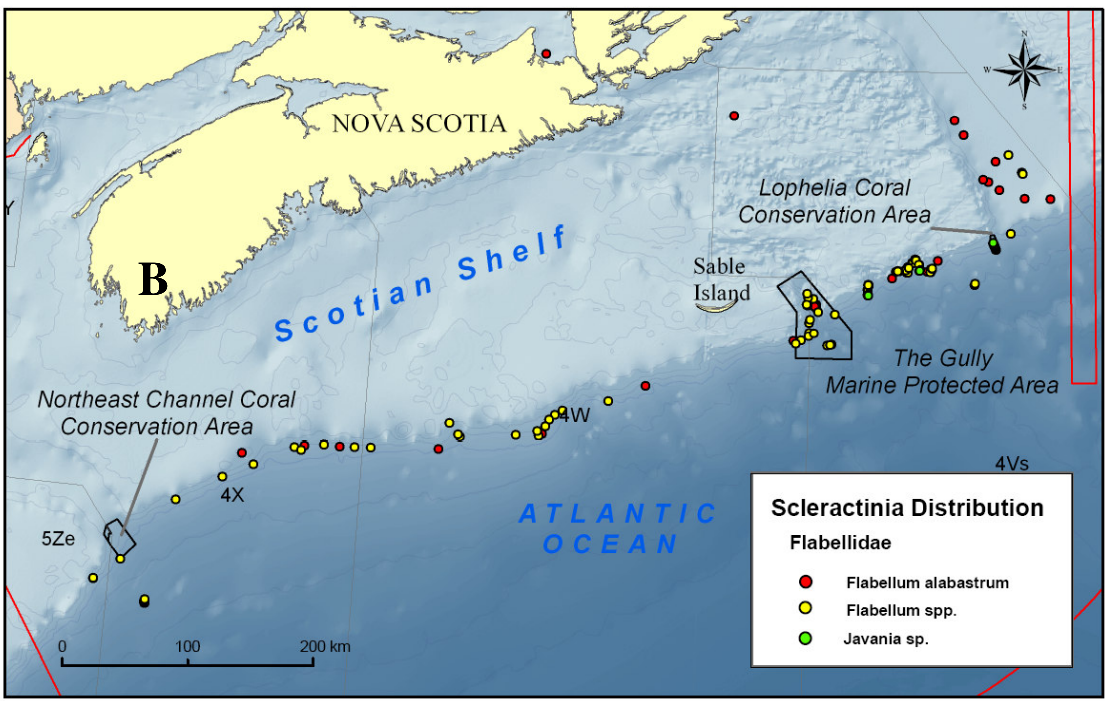


Figure 16. Taxa within the family Caryophyllidae (**A**), which include *Lophelia pertusa* and *Desmophyllum* spp. Family, Flabellidae (**B**) represented by *Flabellum alabastrum* and *Javania* sp.

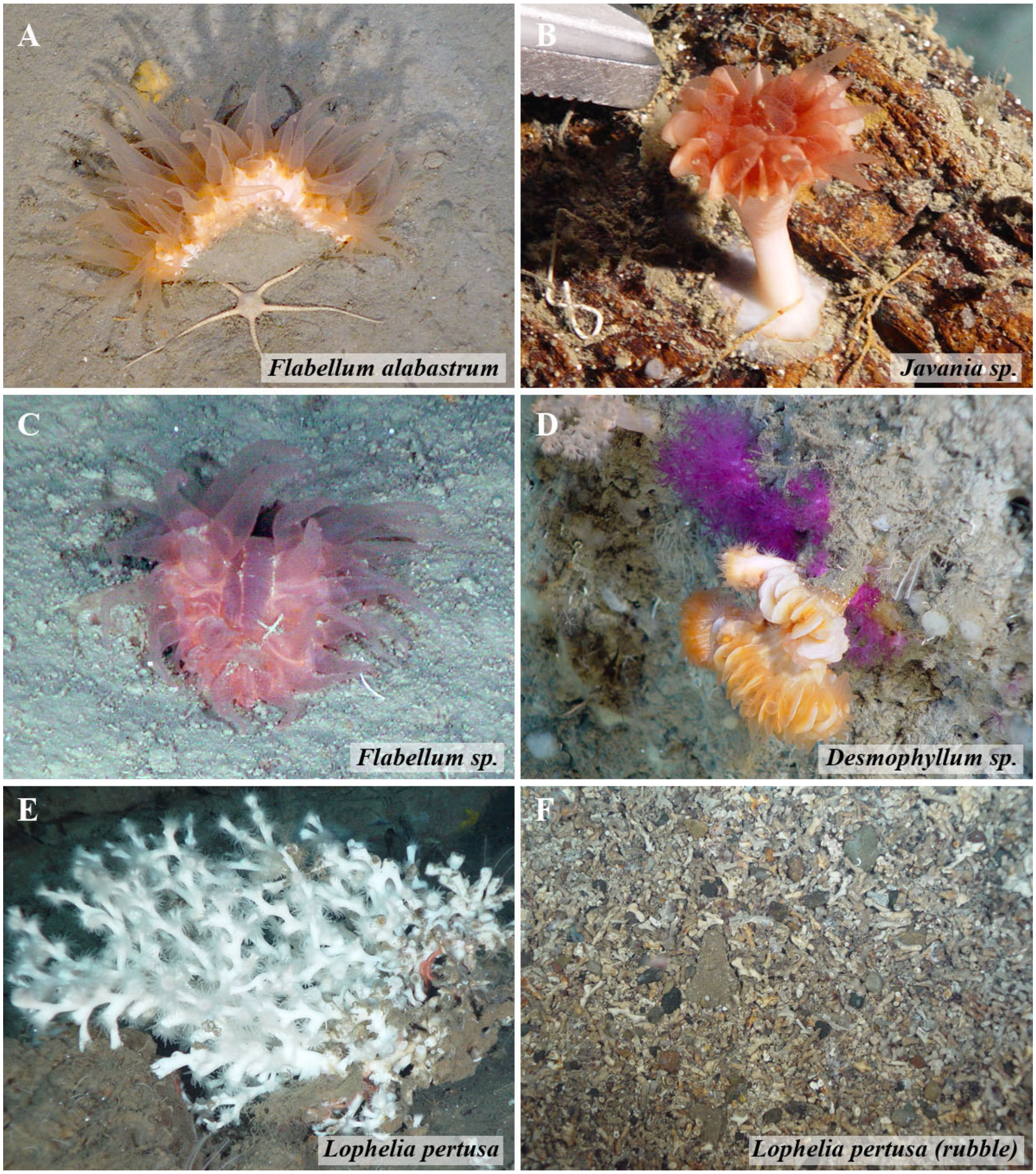


Figure 17. **A-C** - represent 3 separate species in the family Flabellidae. **D-F** – *Desmophyllum* sp. and *Lophelia pertusa* are species in the family Caryophyllidae. **F** – This picture of *Lophelia pertusa* rubble taken in 2007 by ROPOS, is indicative of the damage caused by trawling gear in the *Lophelia* Conservation Area prior to its closure to bottom fishing in June of 2004.

Northeast Channel Coral Conservation Area

NEC Coral Distribution

The most recent compilation of coral records for the NEC CCA was produced by Gordon and Kenchington (2007). Drawing from previous reports they provide details for three gorgonian taxa: *Acanthogorgia armata, Paragorgia arborea* and *Primnoa resedaeformis.* The data presented here extends this species list to include the gorgonian corals *Acanella arbuscula, Keratoisis ornata, Paramuricea* spp., the sea pens *Halipteris* spp., *Kophobelemnon* sp. and *Pennatula* spp., and the soft corals *Anthomastus* spp. and members of the family Nephtheidae, as well as the stony coral *Desmophyllum* spp. Table 5 shows 14 total taxa within the NEC CCA, but by amalgamating the genus *Primnoa* and *Paragorgia* there are 12 taxa actually present (Table 2).

Figure 18 displays the distribution all coral taxa both inside the restricted area and in a 15 km and 45 km buffer surrounding its periphery. The buffers were included because some taxa were found here exclusively and not inside the NEC CCA. Despite the fact that the number of coral records within the 15 km buffer zone was only 1527 compared to 9538 records within the NEC CCA, the 15 km buffer contained 9 taxa not found in the conservation (Table 2). These are the gorgonian corals *Anthothela grandiflora, Paramuricea placomus* and *Radicipes* spp., the sea pens *Anthoptilum grandiflorum, A. murrayi, Kophobelemnon stelliferum,* and *Ombellula* spp., and the stony corals *Lophelia pertusa* and *Flabellum* spp. The average water depth in which taxa unique to the 15 km buffer were found was 1582 ± 195 m with a minimum depth of 1435 m and a maximum depth of 1997 m. Nearly all of the observations came from the analyses of the 2006 ROPOS video and still images. *Lophelia pertusa* is the only exception, with the record on the Northwest edge of the protected area recorded by the Observer Program in 2003. No other confirmed records of *Lophelia* have been seen in this area.

The 45 km buffer zone contains only 229 total records, but introduces another 4 species not present in either the 15 km buffer or the CCA (Table 2). These are the gorgonian *Chrysogorgia agassizii*, the sea pen *Balticina finmarchica*, and some members of the order Antipatharia, including *Stauropathes arctica*. The average depth of these 4 taxa is 2332 ± 124 m with a minimum depth of 1294 m for the 1 record of *Balticina finmarchica* and a maximum depth of 2385 m for *Chrysogorgia agassizii*. The 15 km and 45 km buffer zones add a total of 13 additional taxa not present within the currently surveyed extent of the CCA.

There is ample evidence from this report and other surveys and studies that the 424 km^2 area selected in 2002 for the Northeast Channel Coral Protection Area is optimally positioned to protect the highest density and least impacted branching gorgonians in the area. The increased coral observed in the deep water outside of the CCA is not protected, although the area is not currently fished with trawlers because of the great depth. Nonetheless, an extension of the boundary to include these areas should be considered.

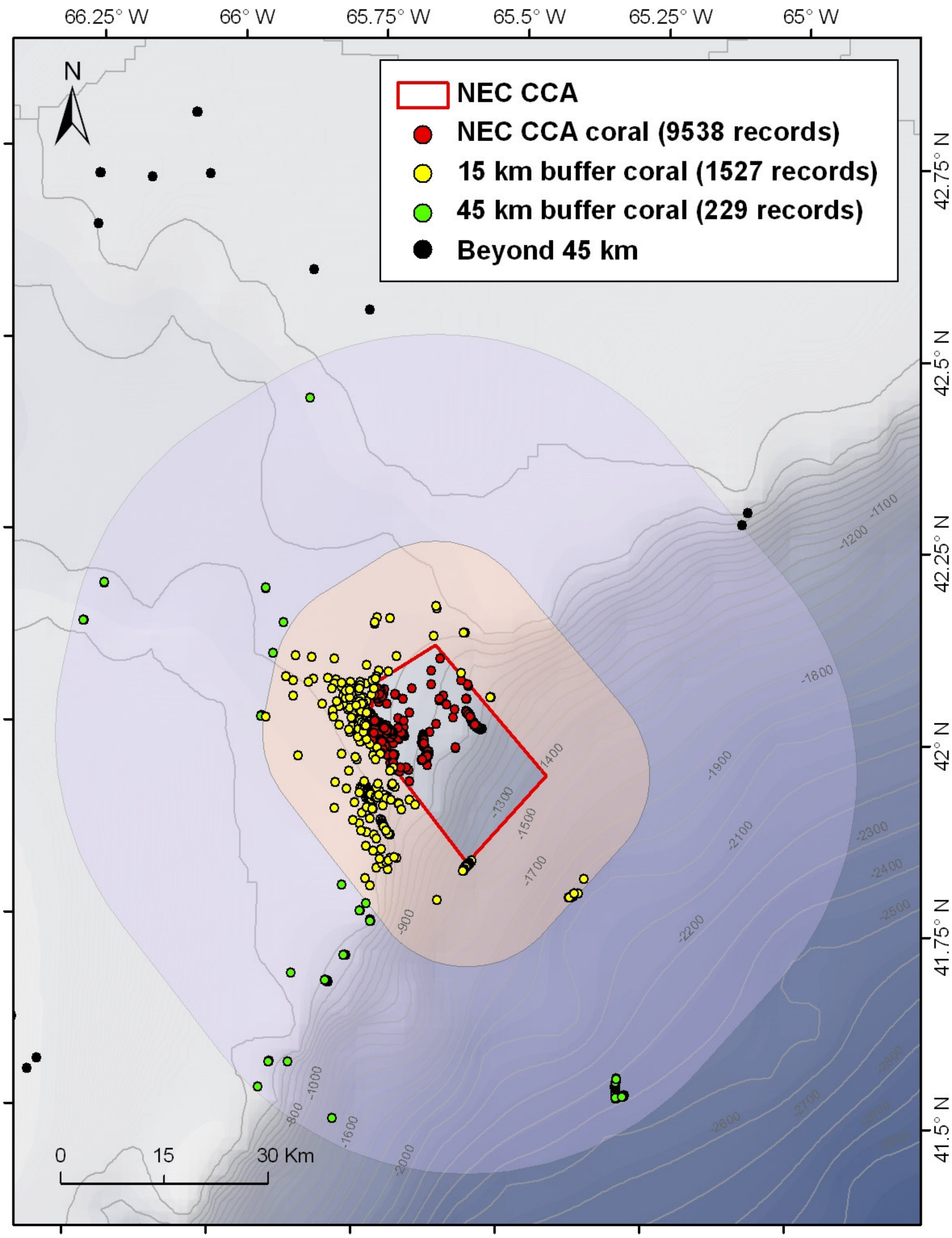


Figure 18. All known coral records plotted within and outside of the NEC CCA (15 km and 45 km buffers to account for deep ROPOS transects in 2006).

Table 2. The taxa list for the NEC CCA and surrounding buffers (15 km and 45 km) as shown in Figure 18. The number 1 denotes presence and an empty cell denotes absence within the footprint of the polygon.

Coral Taxon	ERMS Order	NEC CCA	15 km	45 km
Anthomastus spp.	Alcyonacea	1	1	
Nephtheidae (F.) spp.	Alcyonacea	1	1	
Antipatharia (O.) spp.	Antipatharia			1
*Stauropathes arctica**	Antipatharia			1
Acanella arbuscula	Gorgonacea	1	1	1
Acanthogorgia armata	Gorgonacea	1	1	
*Anthothela grandiflora**	Gorgonacea		1	
*Chrysogorgia agassizii**	Gorgonacea			1
Keratoisis ornata	Gorgonacea	1	1	1
Paragorgia arborea	Gorgonacea	1	1	1
Paragorgia sp.	Gorgonacea	1	1	1
Paramuricea placomus	Gorgonacea		1	1
Paramuricea spp.	Gorgonacea	1	1	
Primnoa resedaeformis	Gorgonacea	1	1	1
Primnoa sp.	Gorgonacea	1	1	1
Radicipes spp.	Gorgonacea		1	
*Anthoptilum grandiflorum**	Pennatulacea		1	
*Anthoptilum murrayi**	Pennatulacea		1	1
*Balticina finmarchica**	Pennatulacea			1
Halipteris spp.*	Pennatulacea	1	1	
Kophobelemnon sp.*	Pennatulacea	1	1	
*Kophobelemnon stelliferum**	Pennatulacea		1	1
Ombellula spp.*	Pennatulacea		1	1
Pennatula spp.*	Pennatulacea	1	1	1
Desmophyllum spp.	Scleractinia	1		
Flabellum spp.	Scleractinia		1	1
Lophelia pertusa	Scleractinia		1	
	Total Count	**14**	**22**	**16**
	Unique Taxa to Polygon	**1**	**4**	**4**

*Species discovered (*Stauropathes arctica, Anthothela grandiflora* & *Chrysogorgia agassizii*) or not reported (ERMS order Pennatulacea) by Gordon and Kenchington (2007). Some species recorded by Gordon and Kenchington (2007), notably the soft corals and *Flabellum*, have been lumped into higher order classification (Nephtheidae (F) spp. and Flabellum spp.) for this paper because their accurate confirmation by video is in question.

Note: F. stands for family and O. for order. Any genus, family or order followed by spp. means there is more than one representative within this classification, whereas sp. denotes just one representative that in most cases has not been confirmed.

Recent Survey Results

In June of 2002, following successive joint DFO and Dalhousie University video surveys in 2000 and 2001, the Northeast Channel Coral Conservation Area (NEC CCA or CCA) was established by the Department of Fisheries and Oceans (Buhl-Mortensen and Mortensen 2004). The area of the protected site is 424 km^2 and consists of a restricted bottom fishing zone (90% of total area) and a limited bottom fishing zone (10% of total area). The conservation area was primarily selected on the basis of having the highest density of large branching octocorals, *Paragorgia arborea* and *Primnoa resedaeformis* (Figure 11), in the Maritimes. In addition, there was visual evidence of recent disturbance such as broken live coral, tilted corals and skeletal fragments, indicating that the large gorgonians were vulnerable to bottom fishing damage. Mortensen and Buhl-Mortensen (2004) ran 45 Campod transects and 7 ROPOS transects traversing the breadth of the canyon based on where branching coral had been recently observed by earlier Campod missions and through bycatch from the Observer Program (Figures 19, 20).

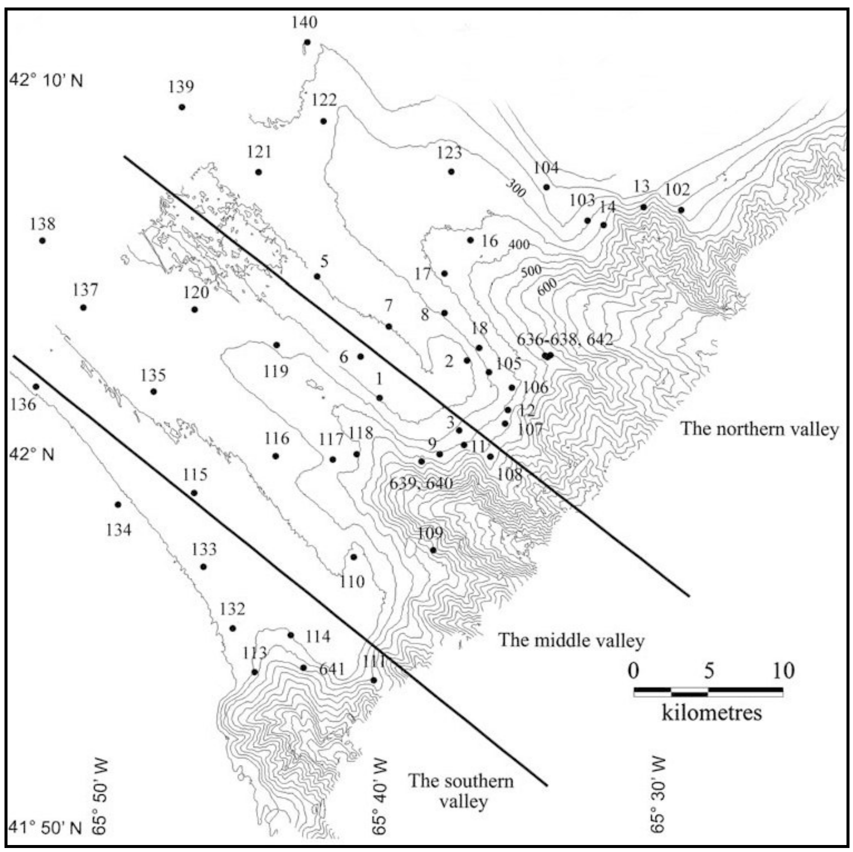


Figure 19. Bathymetry and location of Campod (45 transects) and ROPOS (7 transect – 636-642) from 2000 and 2001 (Mortensen and Buhl-Mortensen 2004).

From the video collected during these surveys the number of *Primnoa resedaeformis, Paragorgia arborea* and *Acanthogorgia armata* colonies per 100 m^2 was calculated. That analysis suggested that the highest density of corals were located in the area that would be eventually designated as the restricted bottom fishing zone (Figure 21). From 2002-2008, subsequent *Primnoa resedaeformis* and *Paragorgia arborea* records have been identified in the area, acquired through numerous sources (Figure 21).

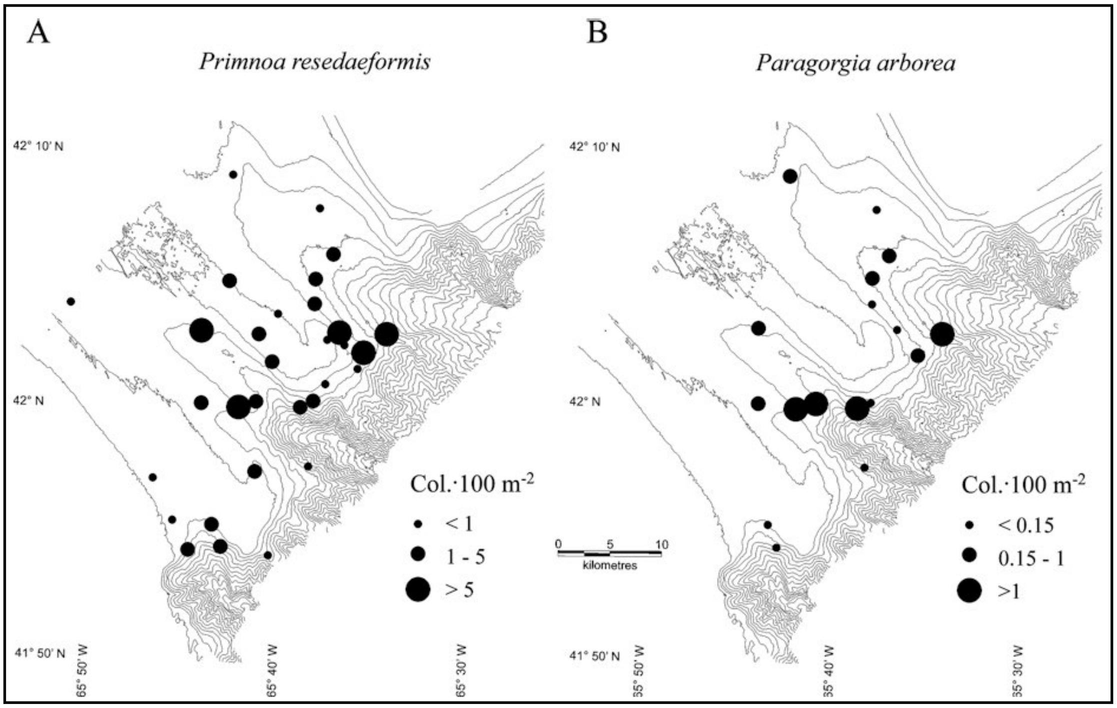


Figure 20. Distribution and abundance of two large branching Gorgonacea in the Northeast Channel (colonies per 100 m^2) (from Mortensen and Buhl-Mortensen 2004).

In an effort to further describe the extent of the northwest boundary of the protected area, a Campod mission in 2005 recorded the physical state of both *Primnoa resedaeformis* and *Paragorgia arborea* seen in video transects inside and outside of the protected areas boundaries (Figure 22 for location of Campod Stations).

The analysis of video acquired from the Campod transects in 2005 (Figure 22) utilized ClassAct Mapper, a software utility developed by Robert Benjamin of Fisheries and Oceans, Canada. When an organism is seen while analysing video, a technician presses a button corresponding to its scientific name and/or condition. The name is then paired with the encoded Greenwich Mean Time (GMT) and ship latitude and longitude from the tape and recorded in an Access database. The GMT for the video analysis table in Access is then used to query the corresponding latitude and longitude information from the gear navigation during the same time period. This georeferenced species information was then plotted with ArcGIS 9.2 (ESRI-Redlands, CA, USA).

A physical description of each *P. resedaeformis* and *P. arborea* colony observed was recorded. Corals were recorded as intact (i.e., no visible damage), damaged or fragmented (colony suffered mechanical damage to all or part of the skeleton), and dead (colony without live polyps, often without color). This particular analysis was not intended to denote differences in damage between the two species, but rather the cumulative effect of fishing damage on both coral species. For this reason, the colony states for each species were pooled.

The area outside of the CCA had a much higher percentage of dead or damaged coral than observed inside the protected area (57% dead or damaged vs. 35%) (Table 3). This presumably reflects damage caused by trawling which is permissible outside the CCA. The dead and damaged coral observed within the CCA cannot be said to entirely reflect natural mortality as trawling could have occurred within the CCA boundaries prior to its designation as a conservation area.

Table 3. Colony state inside and outside of the Northeast Channel Coral Conservation Area. Data from 2005 Campod video transects. Observations on *Primnoa resedaeformis* and *Paragorgia arborea* were combined.

Location Relative to CCA	Intact	Broken/Skeletal Fragment	Dead	Total
Inside	470 (65%)	203 (28%)	48 (7%)	721
Outside	39 (43%)	43 (47%)	9 (10%)	91

A Kernel Density Analysis of damaged coral (using the numbers of coral with **Broken** and **Skeletal** fragments) was performed to spatially illustrate the areas with the highest density of damage (Figure 22). The data were standardized to a proportion of damaged coral on each transect, and a density plot was calculated around a 5 km search radius for each cell. The cell size was taken as the ArcGIS calculated default which is 1/250th of the largest axis (vertical or horizontal) of the data extent. For each cell it totals the number of points that fall within a 5 km radius and divides that number by the area (Mitchell 1999).

Figure 22 shows that the centre for maximum mechanical damage *Paragorgia arborea* and *Primnoa resedaeformis* lies within the restricted fishing zone and extends just outside of the CCA. The damage to corals outside the CCA (Table 3) appears to be localized.

A similar analysis was performed utilizing video gathered from ROPOS in 2006 using the same data acquisition software as described above. The preliminary physical assessment of both *Paragorgia arborea* and *Primnoa resedaeformis* were more specifically described as: Intact, tilted, broken colony, live branch on seafloor, skeletal fragment, zoanthid coverage (a known parasite of some gorgonians which can ultimately smother colonies) and dead**.** For the density analysis these coral "states" were re-classified as: **Intact** or **Mechanically disrupted** (tilted, broken colony, live branch on seafloor – this does not necessarily mean disruption by fishing, as tilted could just as well mean that the colony fell over due to its own weight), or **Dead** (including zoanthid infestation and skeletal fragments). While skeletal fragments could also indicate **Mechanical disruption**, they could also occur during natural mortality as the coral begins to fall apart.

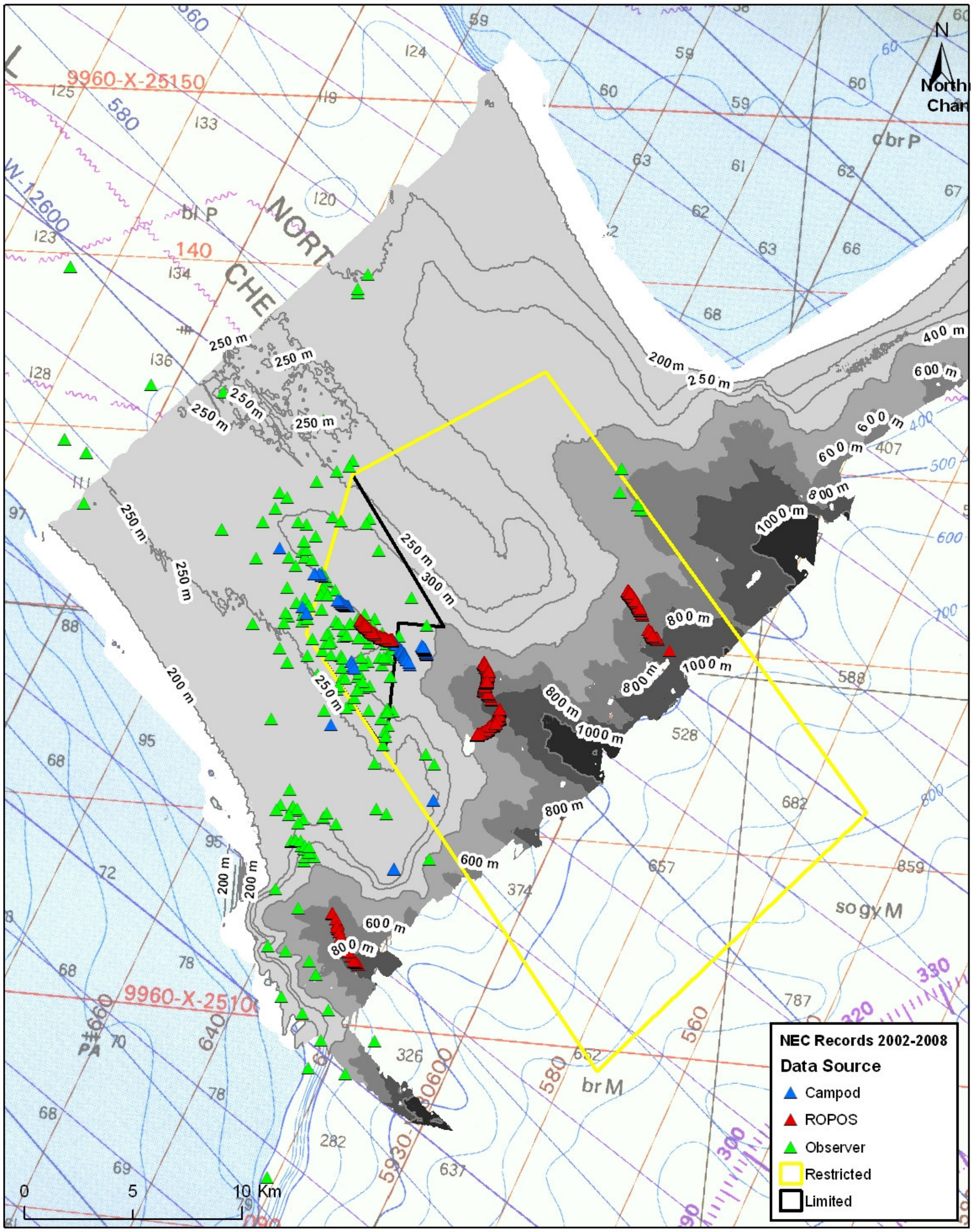


Figure 21. Both the restricted and limited fishing zones contain *Paragorgia arborea* and *Primnoa resedaeformis.* Shown here are records from both species collected after 2001 by three different methods, Campod, ROPOS and confirmed records from the Observer Program.

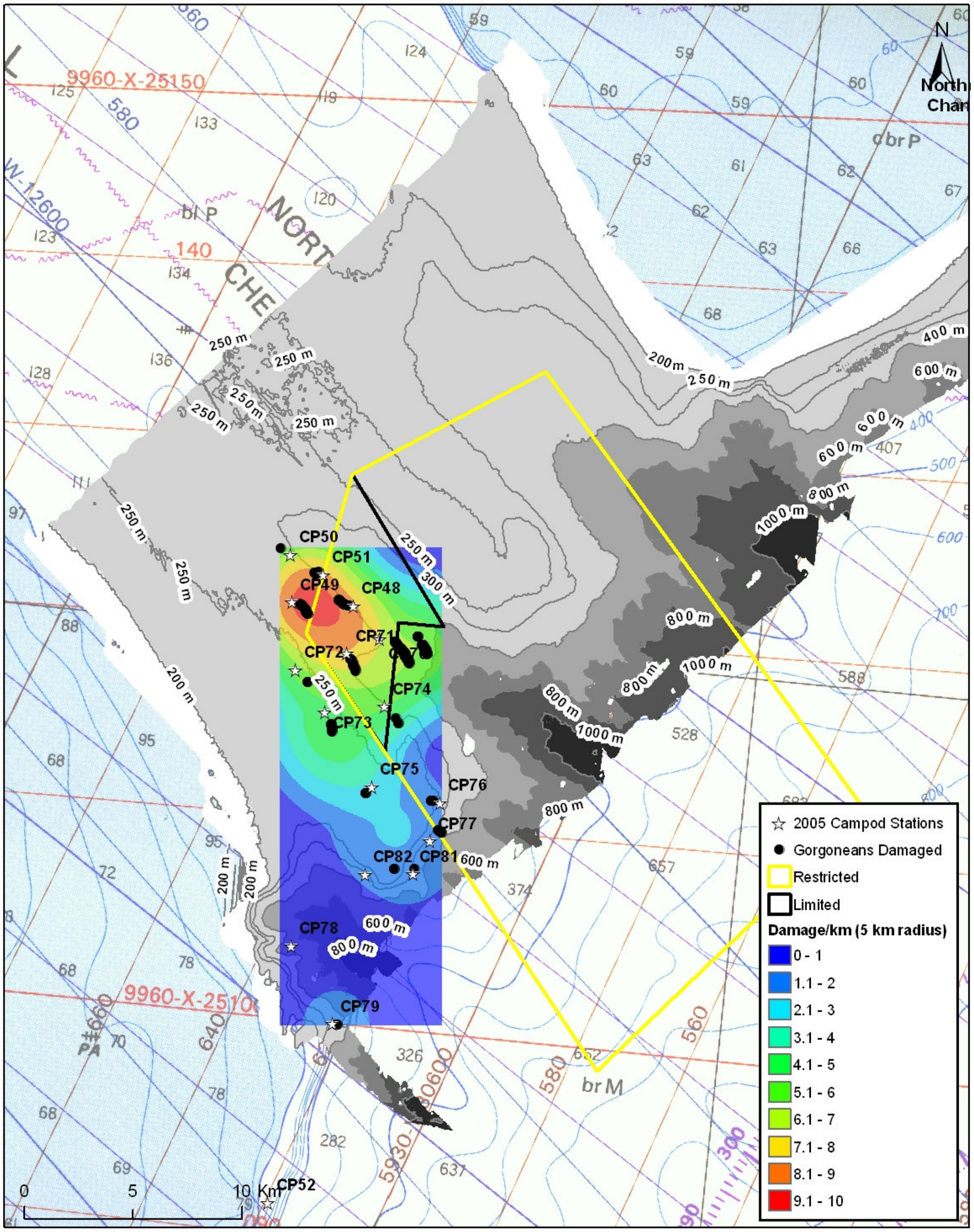


Figure 22. 2005 Campod stations (star) overlying a kernel density analyses indicating the areas with the greatest amount of damage to *Paragorgia arborea* and *Primnoa resedaeformis*. Red areas show areas of high damage while blue areas indicated low or no damage.

For each colony state, counts were gathered for each species at 300 m depth intervals for each dive (Table 4). Only some of the dives had records collected over more than 900 m (974 and 982) and those were excluded. A Bray-Curtis similarity matrix derived from the log transformed input indices was calculated with Primer 6 (Primer-E, Plymouth, UK) and data were clustered using a UPGMA clustering algorithm and the significance of the nodes calculated (using CLUSTER and SIMPROF subprograms respectively). For the dives examined, colony state was not a function of depth or their location either inside or outside (only dive 982) of the conservation area (Figure 23 and Table 5). Figure 23, A Multi-Dimensional Scaling plot using the Bray-Curtis similarity matrix, shows that in general the colony state for *Paragorgia* resulted in this taxa grouping separately from most *Primnoa.* While there are some incidences of *Paragorgia* grouping with *Primnoa,* there is only one case (Dive 976 at 900m) where the 2 taxa within the same dive were more than 90% similar according to the log transformed Bray-Curtis similarity matrix (Figure 24). This suggests that that there is a generalized species specific ratio of colony state.

Table 5 shows that the difference in colony state percentages between *Primnoa* and *Paragorgia,* whether inside or outside the conservation area, remain consistent. For both locations and taxa, the percentage of mechanically disturbed records ranges from 3-7%. Conversely, the proportion of intact *Paragorgia* recorded was 20-22% less than the proportion of intact *Primnoa.* According to these observations the reduced incidence of **Intact** *Paragorgia* was inversely proportional to a 19-25% higher incidence of **Dead** *Paragorgia.* A further break down of the **Dead** condition counts for *Paragorgia* shows 348 (79%) skeletal fragments and 95 (21%) dead records. *Primnoa* shows 467 (64%) skeletal fragments, 51 (7%) zoanthid infestation, and 212 (29%) dead records. While not discussed further within this report, zoanthid infestation could be a possible indicator of *Primnoa* health.

The 20% higher incidence of **Dead** *Paragorgia* could be explained in a number of ways: **1.** while the proportion of the **Dead** indices is 15% more likely to be skeletal fragments for *Paragorgia*, the large size of *Paragorgia* skeletal fragments also make them more conspicuous during video analysis, **2.** *Paragorgia* could just be more likely to shed dead branches as the organism ages, and **3.** *Paragorgia* are displaying an increased level of proportional mortality compared to *Primnoa*. Given that there are ~20% proportionally fewer intact *Paragorgia* than *Primnoa*, an increase in *Paragorgia* mortality seems the most likely explanation. Nonetheless, another possibility is that a mechanical disruption in the distant past had disproportionately impacted *Paragorgia.* Given that both taxa persist for many hundreds of years and have very slow growth rates (Sherwood and Edinger 2009), the evidence for a mechanical disruption of such an impact (tilted colonies, broken colonies, live branch on sea floor) would long ago have dissipated with the only remaining evidence being an increase in the number of skeletal fragments as is evident for *Paragorgia*. Whatever the reason, more work needs to be conducted in the NEC CCA to ascertain whether this difference in **Dead** and **Intact** *Primnoa* and *Paragorgia* is a recent phenomenon or is the artefact of a historical impact which preferentially affected *Paragorgia.*

Table 4. The number of Dead (D), Intact (I) and Mechanically Disrupted (M) colonies for *Paragorgia arborea (Para)* and *Primnoa resedaeformis (Prim)* in the Northeast Channel Coral Conservation Area. Observations were made with ROPOS in 2006 (see Figure 21). The numbers are presented for 3 depth strata (to 300, 301-600, 601-900) and by dive (972, 974, 975, 976, 977, 978, and 982). Only dive 982 falls outside of the protected area.

Taxa	**Code**	**972 600**	**974 600**	**974 900**	**975 300**	**975 600**	**976 600**	**976 900**	**977 900**	**978 900**	**982 900**
Para	D	1	54	120	55	29	14	84	44	35	7
Para	I	20	35	185	18	31	57	95	52	36	9
Para	M	0	0	8	3	1	8	8	1	3	1
Prim	D	33	172	147	80	72	60	65	59	12	30
Prim	I	102	711	623	338	201	277	200	259	92	96
Prim	M	7	70	71	26	9	14	22	21	7	5

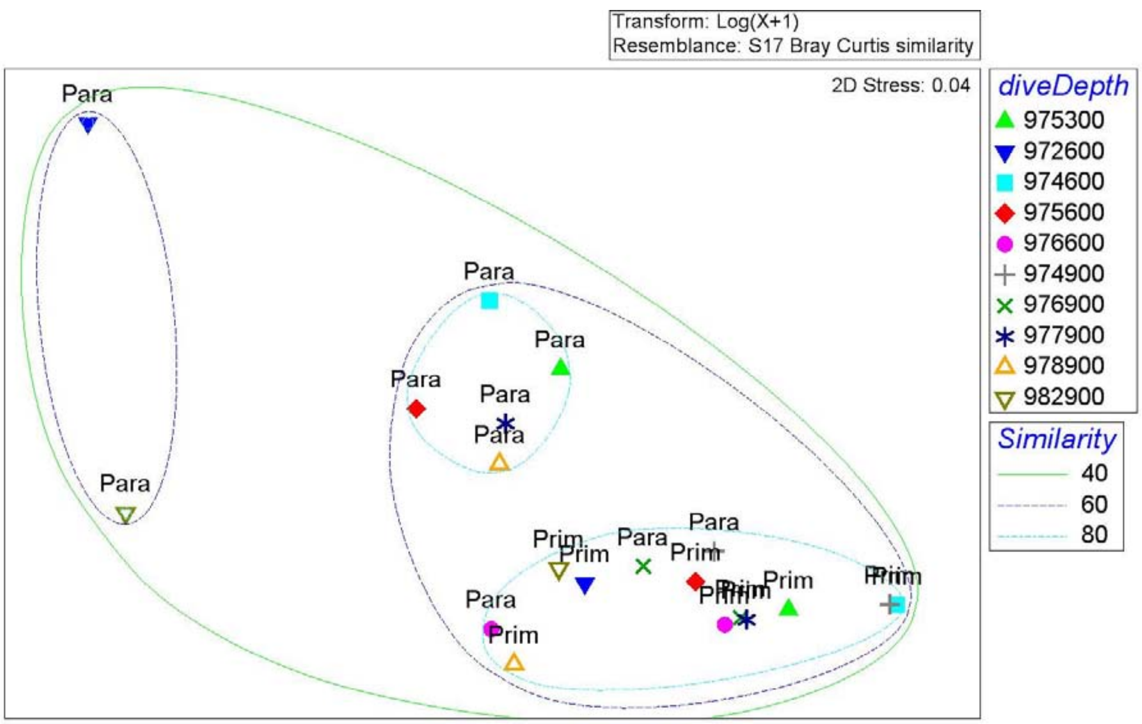


Figure 23. A Multi-Dimensional Scaling (MDS) plot of the Bray-Curtis similarity index among transect/depths by coral genus (*Paragorgia, Primnoa)* (see Table 4). Clusters with 40, 60 and 80% similarity are illustrated.

Table 5. The count, ratio and percent for each colony state, (Intact, Disturbed and Dead) inside the protected area and out. The MDS plot revealed clumping by species. The data suggests a 22% increase in Intact *Primnoa* colonies with a corresponding 22% decreased incidence of dead *Primnoa* colonies as compared to *Paragorgia* colonies within and outside of the CCA.

	Intact	**Disturbed**	**Dead**	**Total Count**
Inside CCA Count	3332	279	1136	4747
Inside CCA Ratio	12	1	4	
Inside CCA Percent	70	6	24	
Outside CCA Count	105	6	37	148
Outside CCA Ratio	18	1	6	
Outside CCA Percent	71	4	25	
Inside CCA				
Paragorgia Count	529	32	436	997
Paragorgia Ratio	17	1	14	
Paragorgia Percent	53	3	44	
Primnoa Count	2803	247	700	3750
Primnoa Ratio	11	1	3	
Primnoa Percent	75	7	19	
Outside CCA				
Paragorgia Count	9	1	7	17
Paragorgia Ratio	9	1	7	
Paragorgia Percent	53	6	41	
Primnoa Count	96	5	30	131
Primnoa Ratio	19	1	6	
Primnoa Percent	73	4	23	

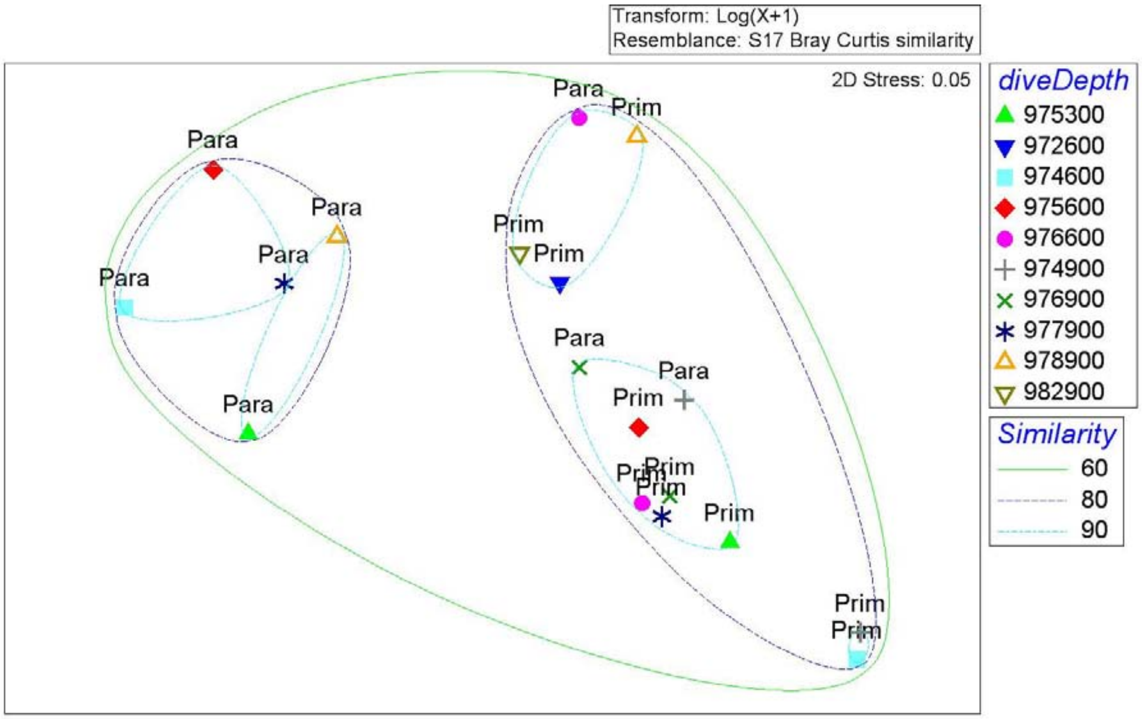


Figure 24. A Multi-Dimensional Scaling (MDS) plot of the Bray-Curtis similarity index among transects/depths by coral genus (*Paragorgia, Primnoa)* (see Table 3). This plot zooms in on the two main clusters and reveals that only one dive (976) at one depth interval (900 m) is more than 90% similar between the 2 coral taxa.

The Gully Marine Protected Area

In 2004 the Department of Fisheries and Oceans Canada designated the Gully as a Marine Protected Area (Figure 25) with the objective of protecting both the endangered bottlenose whale and the great diversity of coral species observed there. Activities that disturb, damage, or remove organisms or their habitat are not permitted within the MPA (EPO 2006). The Gully MPA is 2364 km^2 and has been divided into 3 zones, with varying levels of management for each zone (Figure 25). Zones 1 and 2 currently house 99.8% of the coral records within the MPA. Within the area of zone 1, the majority of sampling has occurred on the Western canyon wall. Little is known of the benthos on the Eastern canyon wall.

Gully Coral Distribution

In the recently compiled Maritimes Coral Data Repository ten data sources contribute to coral data points in the Gully (Table 6), with the majority of records acquired in 2007 with ROPOS and in 2008 with Campod.

Table 6. The complete dataset of coral records observed in the Gully MPA.

Source	Type of Survey	Gear Type	Year	Count
TEK (Traditional Ecological Knowledge)	N/A	Variable	N/A	32
Maritime Observer Program	Observer	Variable	N/A	1
Campod	Benthic Survey	ROV	1997	9
Campod	Benthic Survey	ROV	1999	18
Campod	Benthic Survey	ROV	2000	4
Campod	Benthic Survey	ROV	2001	77
DFO Groundfish Survey	Trawl	Western IIA	2003	2
DSIS*	Benthic Survey	ROV	2006	216
ROPOS*	Benthic Survey	ROV	2007	18308
Campod*	Benthic Survey	ROV	2008	10093

*Surveys not covered in Gordon and Kenchington 2007.

Gordon and Kenchington (2007) list 5 **Alcyonacea** *(Anthomastus grandiflorus*, *Duva florida*, 3 Nephtheidae taxa), 6 **Gorgonacea** (*Acanella arbuscula*, *Acanthogorgia armata*, *Keratoisis ornata*, *Paragorgia arborea*, *Primnoa resedaeformis*, *Radicipes gracilis*) and 5 **Scleractinia** (*Flabellum alabastrum*, *Flabellum macandrewi*, *Flabellum* cf. *angulare*, *Flabellum* spp. and *Lophelia pertusa* (unconfirmed)). The 2007 ROPOS mission collected nearly 90 hours of geo-referenced video and 1034 high resolution images over 6 dives covering ~ 34 km of ocean bottom. The video has been analyzed utilizing ClassAct Mapper, as described previously, and was subsequently plotted with ArcGIS 9.2 (ESRI Canada Ltd, Redlands, CA). During this mission 11 new coral taxa were discovered or confirmed for the first time in the Gully MPA (Table 7).

Table 7. This is a list of taxa discovered by ROPOS in 2007 that had previously been unreported or unconfirmed in the Gully MPA.

Coral Taxon	**ERMS Order**
Antipatharia spp.	Antipatharia
Chrysogorgia agassizii	Gorgonacea
Anthothela spp.	Gorgonacea
Paramuricea spp.	Gorgonacea
Pennatula aculeata	Pennatulacea
Pennatula borealis	Pennatulacea
Halipteris finmarchica	Pennatulacea
Anthoptilum grandiflorum	Pennatulacea
Anthoptilum spp.	Pennatulacea
Ombellula spp.	Pennatulacea
Kophobelemnon stelliferum	Pennatulacea
Lophelia pertusa	Scleractinia

Using ArcGIS 9.2, the "Extract Values to Points" tool was utilized to extract data from a multibeam elevation and slope grid to the location of each coral record in the Gully (Fader and Strang 2002). Figure 26 shows the distribution of coral taxa in the Gully MPA ranked according to the mean depth of occurrence and Figure 27 ranks the coral taxa according to the mean slope. While there is a large overlap in the taxonomic distribution by depth and slope there are clearly some species which group together at similar slope and depth distributions. These slope and depth data will be utilized in conjunction with recently acquired sediment data from 2007 (grain size, labile and refractory carbon content) to provide a clearer picture of coral habitat preferences (Kenchington, in prep.).

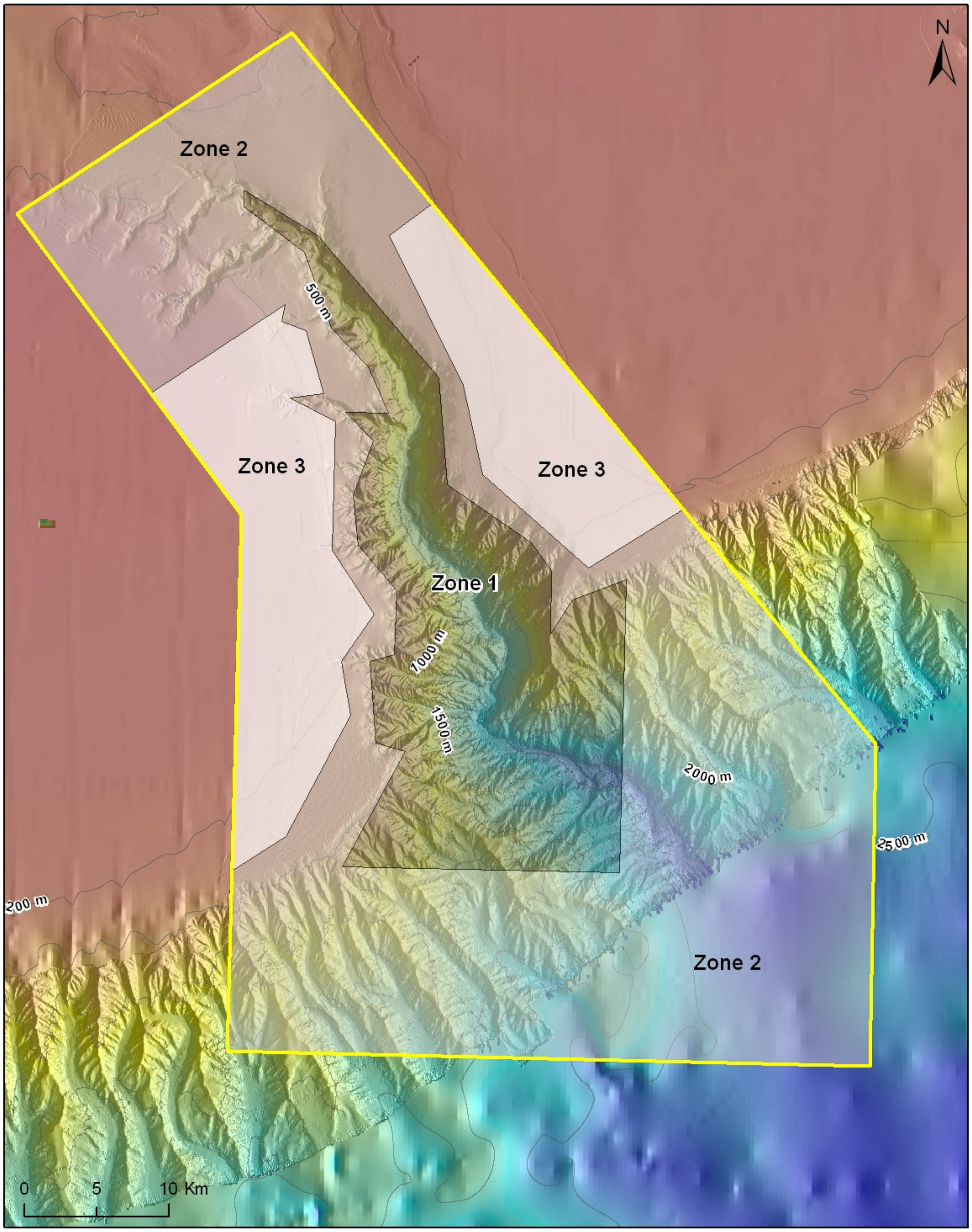


Figure 25. The Gully Marine Protected area. Zones 1, 2 and 3 have different management strategies (EPO 2006).

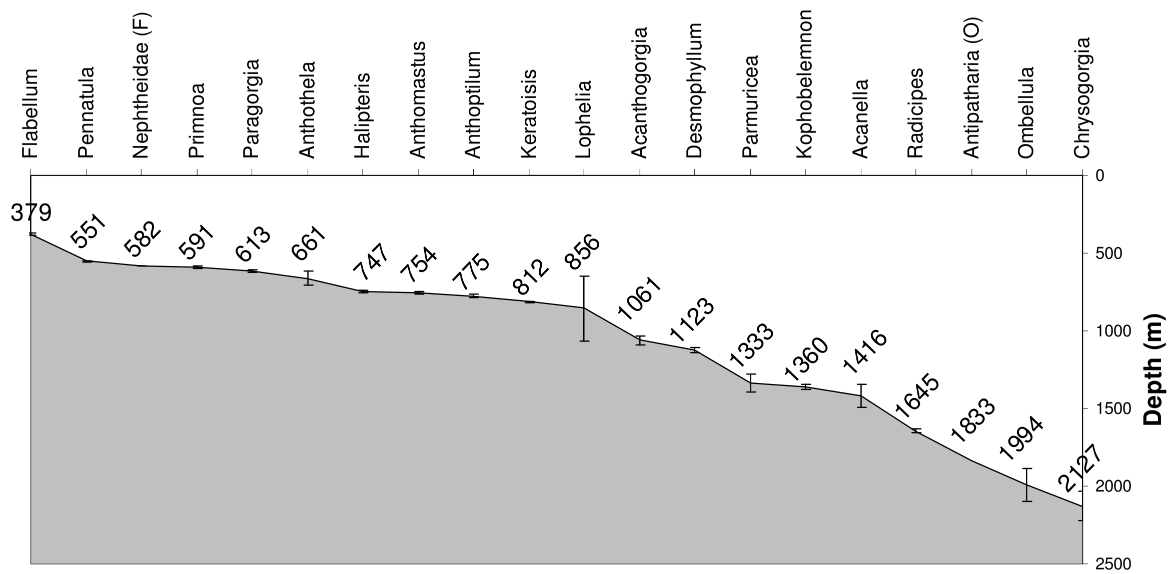


Figure 26. A graphic interpretation of coral taxa distribution by mean depth (± standard error) of occurrence within the Gully MPA.

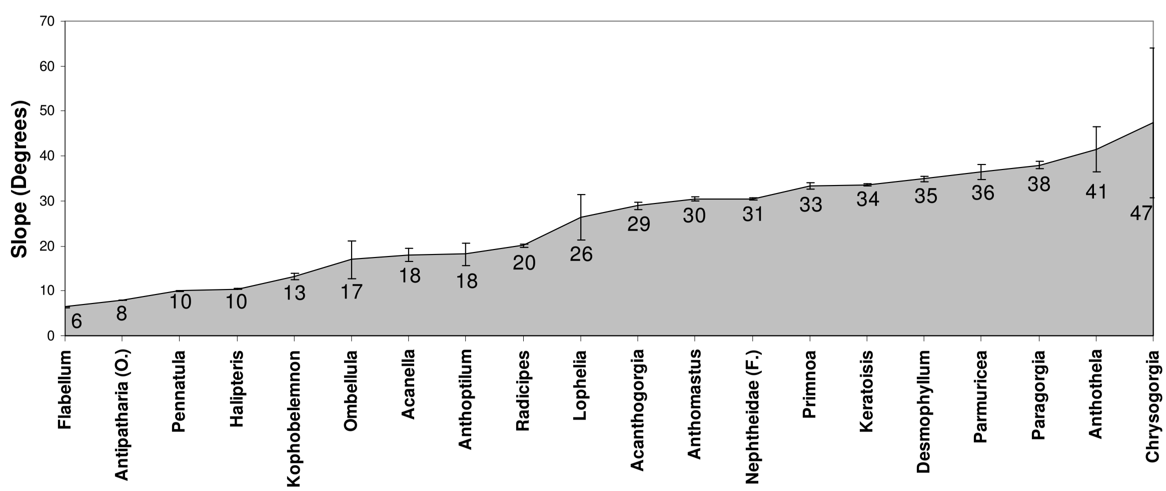


Figure 27. A graphic interpretation of coral taxa distribution by mean slope (± standard error) within the Gully MPA.

The Stone Fence *Lophelia* Conservation Area

The *Lophelia* Conservation Area (LCA) is in an offshore region known to fishermen and others as the Stone Fence. It is located at the mouth of the Laurentian Channel, about 260 km southeast of Louisbourg, N.S. While small colonies of the reef building *Lophelia pertusa* were discovered in the Gully MPA in 2007, until 2007 the only known location of *Lophelia* was discovered at the Stone Fence on a mission led by Dr. Don Gordon aboard the CCGS Hudson in September 2003.

The reef is comprised of both living and dead coral, and has been damaged by fishing activity over the past few decades. In June of 2004 the 15 km^2 *Lophelia* Coral Conservation Area was created in consultation with representatives of active fisheries in the area (EPO 2006) as a 1 nautical mile buffer closed to all bottom fisheries around the known extent of the reef.

A subsequent mission in 2007 collected additional data from the LCA and the deep waters of the Laurentian fan to depths of 2500 m. Data from this mission are being assessed to quantify fishing damage, to define the extent of the *Lophelia* reef, and to identify associated reef taxa.

LCA Coral Distribution

Figure 28 shows the known distribution of all coral taxa within the LCA. Records collected outside of the LCA and along the slope are also included within a 15 and 45 km buffer. Table 8 is a review of the coral records by both taxa and ERMS order in the LCA and in each buffer. As of 2007, 9 taxa had been recorded within the confines of the LCA, and despite the addition of coral records during the 2007 ROPOS mission, there have been no additional coral taxa added to this area since Gordon and Kenchington (2007). In addition, none of the taxa within the bounds of the LCA are unique as compared to either the 15 or 45 km boundary. This emphasizes that the boundary was selected to protect an abundance of just one coral taxa (*Lophelia pertusa*). Records from the 15 km boundary (largely represented by a single 2007 ROPOS dive - 1063) contain 30 taxa, of which 7 are unique to this polygon (*Alcyonium multiflorum*, *Anthothela grandiflora*, *Funiculina* sp., *Javania* sp., *Paramuricea placomus*, *Pennatula* spp., and *Stichopathes* spp). This is a similar trend observed in and around the NEC CCA and is purely a function of a group of taxa which reside in greater water depth south of the LCA (971 ± 247 m). Records within the 45 km boundary (represented mostly by 2007 ROPOS dive - 1062) contain 28 taxa, of which 4 are unique (*Anthomastus* spp., *Anthoptilum* spp., *Chrysogorgia agassizii*, *Drifa glomerata*, and *Flabellum alabastrum*). Both *Chrysogorgia agassizii* and *Anthoptilum* spp. were found in water depths greater than 2000 m. While the focus of the LCA is to protect the known extent of a *Lophelia* reef, extending the boundaries into the deeper waters of the Scotian Slope would help protect a greater diversity of coral taxa.

Recent Survey Results

DFO led Surveys in 2003 and 2007 showed an extensive distribution of *Lophelia* rubble and other evidence of bottom fishing, such as lost gear and overturned rocks. In an effort to assess areas most impacted by fishing damage, *Lophelia pertusa* colony state (**Live, Rubble,** or **Dead)** was noted during the analysis of the 2003 Campod video. *Lophelia* colony state was recorded using ClassAct Mapper. Encoded geo-referenced location data for each record of *Lophelia* was stored in an Access Database by ClassAct Mapper prior to interpretation. Using the data collected during the analysis, the extent of the reef was plotted by the three recorded coral states (Figure 29). Ellipses demarcating the directional standard deviation around the mean location for both live and dead/rubble *Lophelia* were created using the "Standard Deviational Ellipse" tool from CrimeStat III software (Ned Levine & Associates, Houston, TX) (Figure 29). This shows that while there is a large overlap between each coral state, there are areas in which both live *Lophelia* and dead/rubble *Lophelia* dominate. The majority of live *Lophelia* reside in the upper northwest corner of the reef while the southeast is largely dominated by dead or rubble *Lophelia.*

A subsequent mission aboard the CCGS Hudson in 2009 revisited high density areas of both live and dead *Lophelia* described in 2003. Video and digital still images are being analyzed for signs of recovery or an alteration in the known extent of live *Lophelia*. In addition, transects were run in areas with no *Lophelia* distribution information so the full reef extent can be described.

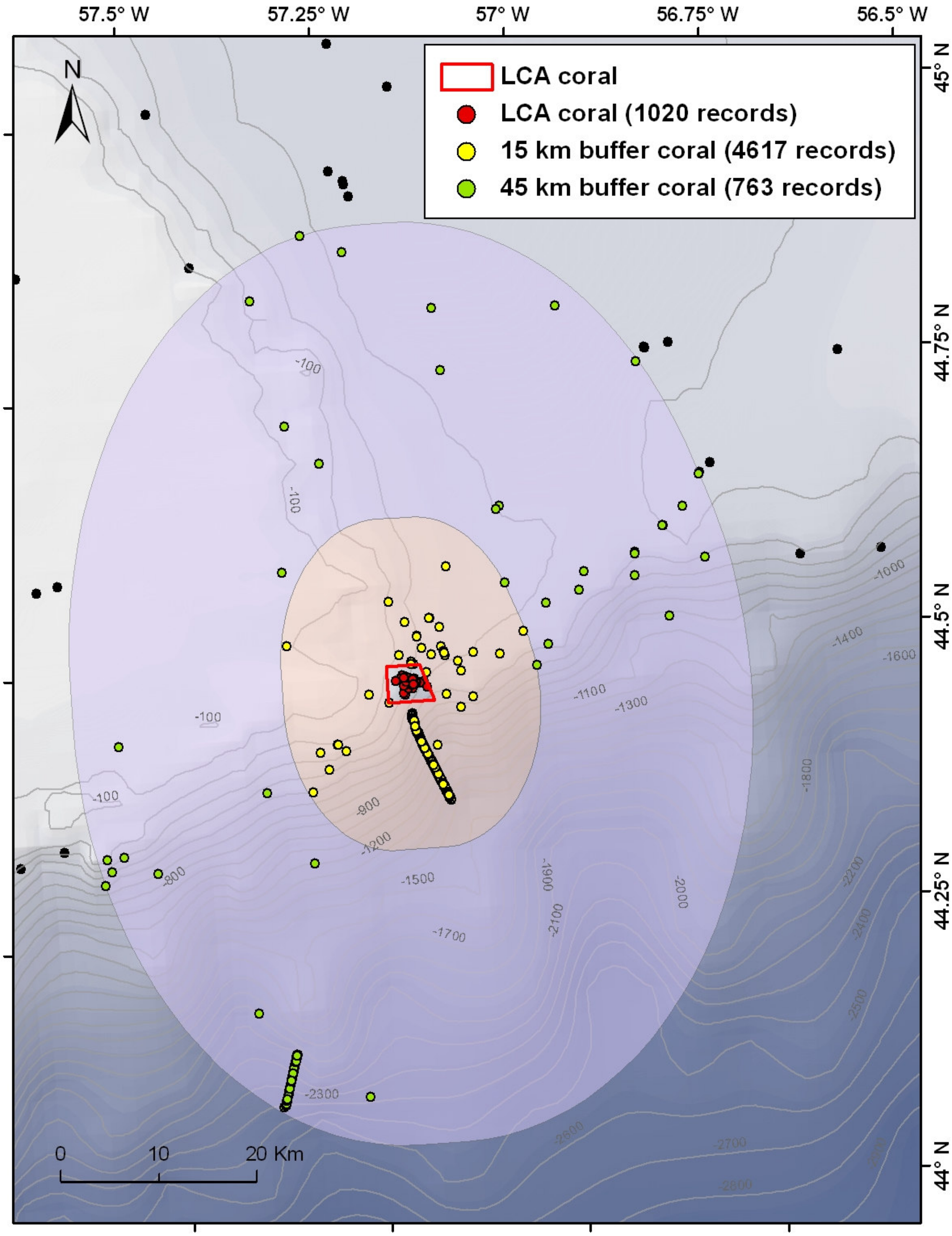


Figure 28. All known coral records plotted within and outside (15 km and 45 km buffers to account for deep ROPOS transects in 2006) of the LCA.

Table 8. The taxa list for the LCA and surrounding buffers (15 km and 45 km) as shown in Figure 29. The number 1 denotes presence and an empty cell denotes absence within the footprint of the polygon.

Coral Taxon	ERMS Order	LCA	15 km	45 km
Alcyonium multiflorum	Alcyonacea		1	
Anthomastus grandiflorus	Alcyonacea	1	1	1
Anthomastus spp.	Alcyonacea			1
Drifa glomerata	Alcyonacea			1
Gersemia rubiformis	Alcyonacea		1	1
Nephtheidae (F.) spp.	Alcyonacea	1	1	1
Antipatharia (O.) spp.	Antipatharia		1	1
Stichopathes spp.	Antipatharia		1	
Acanella arbuscula	Gorgonacea		1	1
Acanthogorgia armata	Gorgonacea	1	1	1
Acanthogorgia spp.	Gorgonacea	1	1	1
Anthothela grandiflora	Gorgonacea		1	
Chrysogorgia agassizii	Gorgonacea			1
Gorgonacea (O.) spp.	Gorgonacea	1	1	1
Keratoisis ornata	Gorgonacea	1	1	1
Paragorgia arborea	Gorgonacea	1	1	1
Paragorgia johnsoni	Gorgonacea		1	1
Paramuricea placomus	Gorgonacea		1	
Paramuricea spp.	Gorgonacea		1	1
Primnoa resedaeformis	Gorgonacea	1	1	1
Radicipes spp.	Gorgonacea		1	1
Anthoptilum grandiflorum	Pennatulacea		1	1
Anthoptilum spp.	Pennatulacea			1
Funiculina sp.	Pennatulacea		1	
Kophobelemnon stelliferum	Pennatulacea		1	1
Ombellula spp.	Pennatulacea		1	1
Pennatula aculeata	Pennatulacea		1	1
Pennatula borealis	Pennatulacea		1	1
Pennatula spp.	Pennatulacea		1	
Pennatulacea (O.) spp.	Pennatulacea		1	1
Desmophyllum spp.	Scleractinia		1	1
Flabellum alabastrum	Scleractinia			1
Flabellum spp.	Scleractinia		1	1
Javania sp.	Scleractinia		1	
Lophelia pertusa	Scleractinia	1	1	1
	Total Count	**9**	**30**	**28**
	Unique Taxa	**0**	**7**	**5**

Note: F. stands for family and O. for order. Any genus, family or order followed by spp. means there are more than one representative within this classification, whereas sp. denotes just one representative that in most cases has not been confirmed.

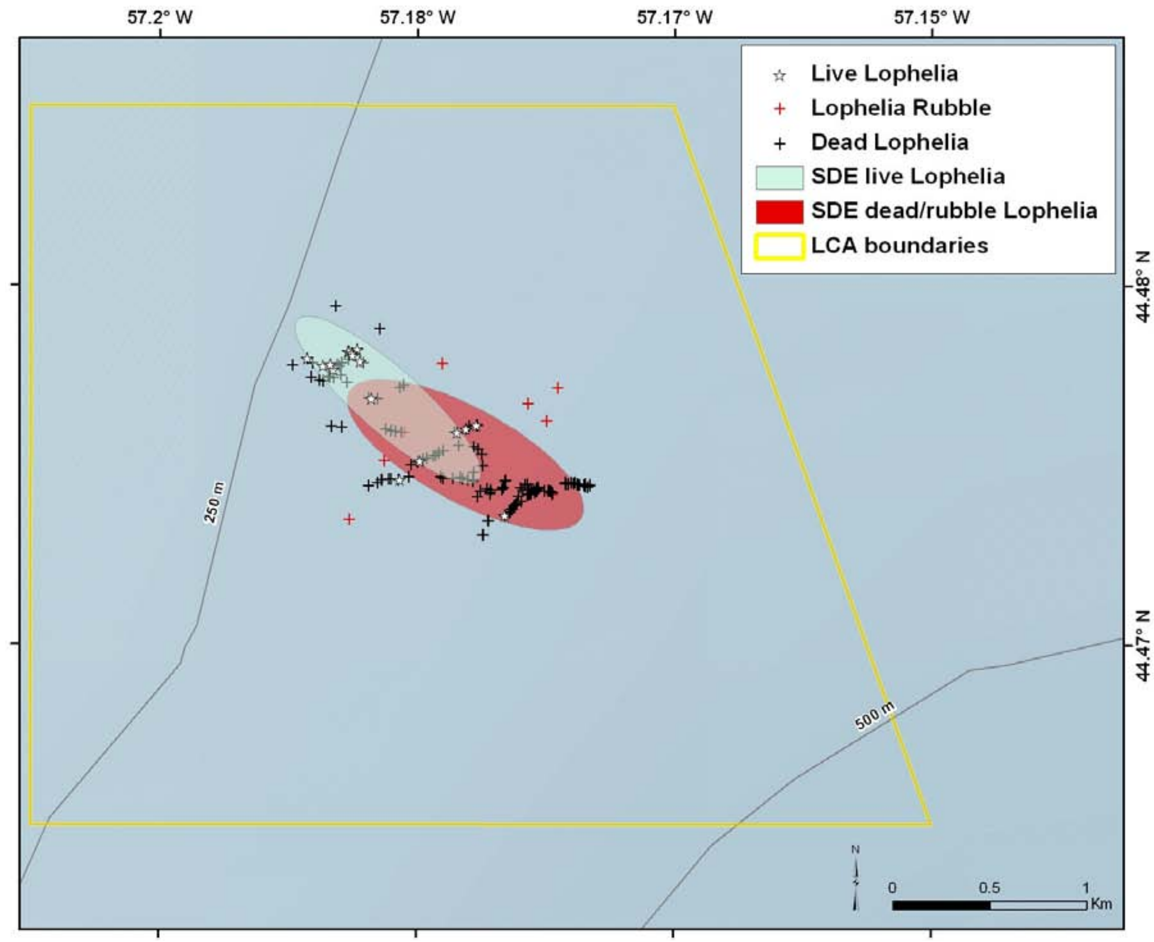


Figure 29. The distribution of Live, Dead and Rubble *Lophelia pertusa* within the boundaries of the LCA (2003 Campod). Included are the directional standard deviational ellipses based on the mean spatial distribution of both live and dead coral.

Protected Areas Summary

A direct comparison between taxa within the boundaries of each protected area shows a marked dissimilarity between each of the three protected areas in terms of coral diversity (CCA = 14 taxa, Gully = 20 taxa, and LCA = 9 taxa). Such a direct comparison between the areas is of little value given the disparity in spatial extent between them (CCA = 424 km^2, Gully = 2364 km^2, LCA = 15 km^2). Nonetheless, what both sites have in common are intense and repeated sampling efforts with many gear types including, Campod, ROPOS and DFO Fisheries Surveys.

It is unlikely, given the intensity of sampling effort, that future missions to the LCA will reveal many additional coral taxa. The relatively low diversity of the LCA compared to the other two protected areas is a function the LCAs area and habitat coverage; the prevalence of both live and damaged *Lophelia pertusa* colonies determined the LCA perimeter.

Compared to the LCA, the Gully and NEC CCA have had just a small fraction of their surface area inspected by benthic surveys. The entire southeastern half of the NEC CCA remains un-surveyed. This un-surveyed area represents deep water and high slope bathymetry which, as illustrated by ROPOS 2006, holds a different subset of taxa than that found in the shallower waters of the northwestern half.

Due to its large size, shape and unique location which cuts deep into the shelf break, the Gully MPA hosts a variety of habitats from the shallow waters of the Scotian Shelf to the deep waters of the abyssal plains. In addition to the array of possible habitats represented within the Gully MPA, its invaginations and elevated ridges provide a much larger benthic surface than the 2364 km^2 area of the MPA boundaries would suggest. In fact, the diverse bathymetry of the Gully adds at least an additional 239 km^2 to the area represented by the Gully MPA boundary.

Adding buffers around the NEC CCA and LCA to approximate the area covered by the Gully gives a more balanced comparison of diversity between the 3 protected areas. A 15 km buffer around the NEC CCA and a 29.5 km buffer around the LCA gives areas of 2382 km^2 and 2379 km^2 respectively (Figure 30). What is immediately evident observing the coral distribution of the three areas is the intensity of survey effort over specific locations (e.g. CCA and LCA) and the relative lack of coral distribution data in the deep waters of the continental slopes for all three sites. Future benthic surveys within and around each protected area should focus on describing the taxa and habitat in the deep waters at the base of the continental slopes.

Given the variety of sampling methods (e.g. trawling, benthic surveys, etc…) it remains difficult to make a direct comparison between the diversity of species at the three sites even with the additional buffers around the closed areas. Nonetheless, all three sites have coral data acquired through similar benthic survey gear type (i.e. Campod, ROPOS) and trawling gear type (i.e. Western IIA). Each site also has varying numbers of locations within the boundaries identified where coral is present (CCA=7014, Gully=10510 and

LCA=5665). To make a direct comparison, coral locations (numbered from 1-7014 for the NEC CCA for example) were randomized using the “Rand” function in excel. The “Rand” function creates a random number between 0 and 1 in a column next to the sequential number given to the coral from each protected area and its buffer. Sorting both columns by the “Rand” column essentially shuffles the sequential numbers for each location into a random order. Once this was complete for the CCA, Gully and LCA buffered areas, only the first 5665 rows of data were selected so the same numbers of locations were compared for each site. Using this randomized coral location data, Species Accumulation Curves (SACs) were run with 999 iterations using Primer 6 version (Primer-E Ltd., Plymouth, UK). SACs plot and list the increasing total number of different species observed (S), as samples are successively pooled (“Sobs” curve) using presence/absence data from each location. Figure 31 shows that in each location the majority of taxa (80%) are observed within the first 1000 (or the first 17%) locations for each site. Generally, at this point each curve rapidly moves towards an asymptote. This suggests that within boundaries of the area already surveyed at each site (Figure 31), only a few coral taxa remain to be discovered. However, specialized habitats not yet surveyed could reveal new species at all locations.

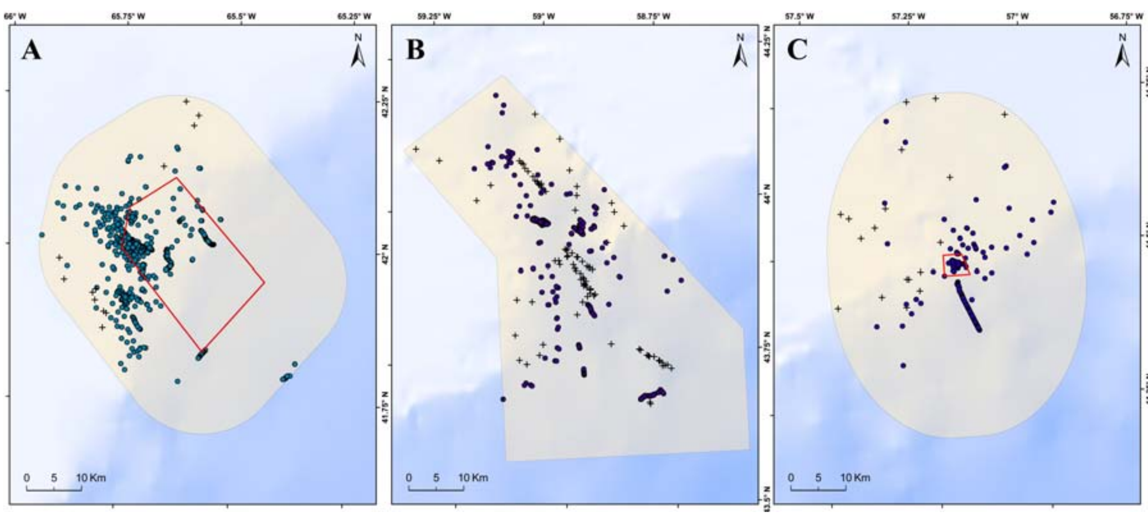


Figure 30. **A** – The Northeast Channel Coral Conservation Area with a 15 km buffer, **B** – The outline of the Gully MPA Boundaries, and **C** – the *Lophelia* Conservation Area surrounded by a 29.5 km buffer. Dots represent coral locations and crosses represent null bycatch records from the DFO Fisheries Surveys.

The SACs indicate that it is reasonable to compare diversity among the three buffered areas since all curves are nearly saturated. In this case, the greatest coral diversity is found in the buffered area of the LCA, with the NEC CCA and the Gully being comparable to one another. Examining the data underlying the SAC for each location (Figure 30) and log transforming the location axis (x) reveals some additional information about each site (Figure 32). For example, the Gully reaches 80% saturation after only 679 locations (12%) suggesting that over the extent of the coral locations used to create the SACs, only a relatively small number of locations are necessary to describe 80% of the total taxa accumulated over the entirety of the curve. This suggests that while the Gully is slightly more diverse than the CCA within the confines of the currently surveyed area, the coverage of dominant coral taxa are comparatively ubiquitous within the surveyed area of the Gully. The NEC CCA for example does not reach 80% saturation until 886 locations (16%). The buffered area of the LCA reached 80% SAC saturation at 995 locations (~18%) suggesting that more locations were necessary to describe 80% of the taxa present than either the Gully or the NEC CCA. In addition, the log transformed data in Figure 32 shows that the slope of the linear regression for the LCA (6.9) is greater than either the NEC CCA (4.9) or Gully (4.6). This chart shows that the LCA has the greatest diversity of each of the three areas as well as the greatest rate of coral taxa return within the boundaries identified (Figure 30).

There is no argument that SAC curves for each location would be dramatically altered if additional benthic surveys were conducted in the deep waters of the Scotian Slope. However, for the extent surveyed within each protected area and its buffer, the vast majority of coral taxa have been described. Nonetheless, if due to technological or financial limitations a future benthic survey site must be chosen between the CCA, Gully and LCA but only within the extent currently surveyed, then the area surrounding the LCA would be the obvious choice and would yield the highest rate of return for the least amount of sampling effort.

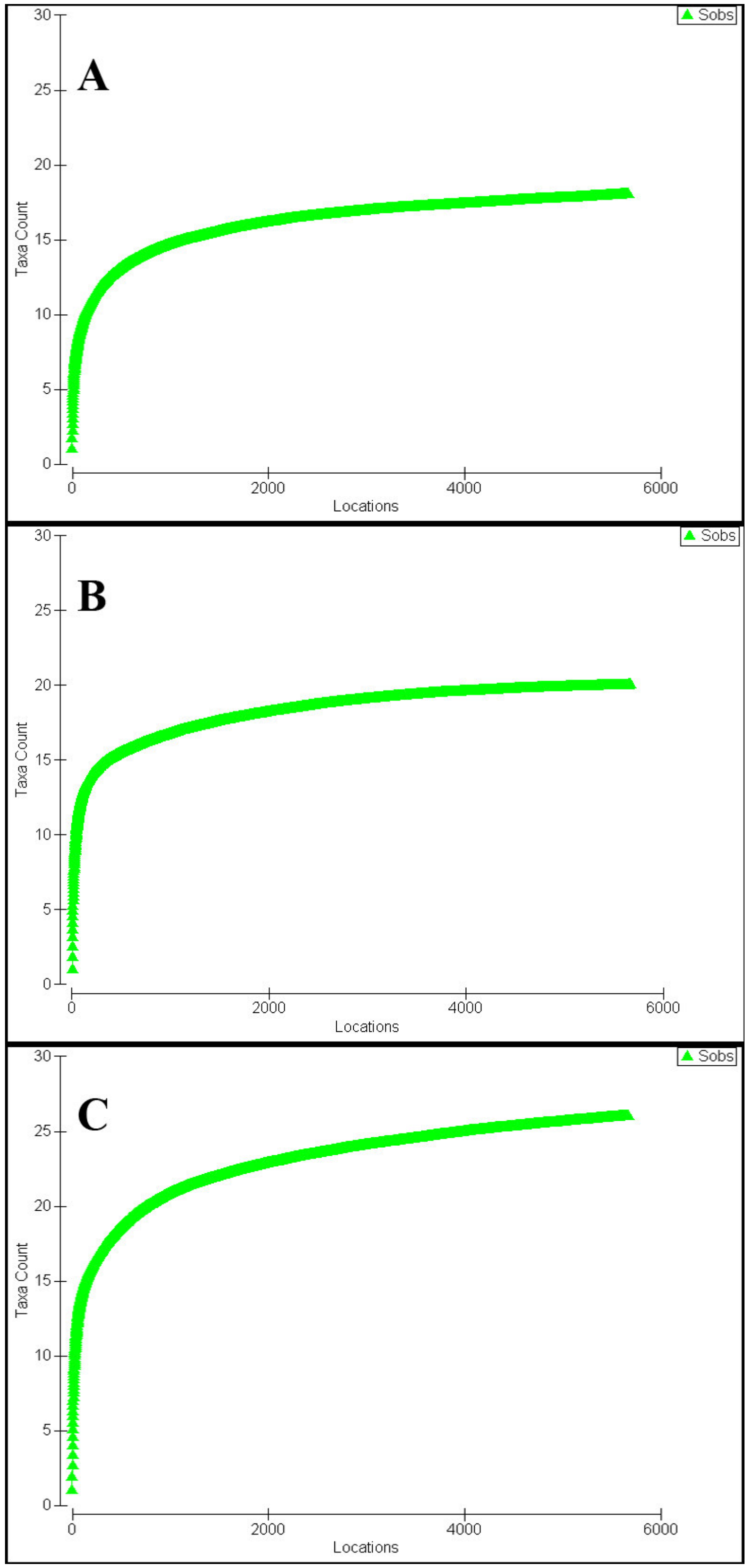


Figure 31. Species Accumulation Curves for, **A.** The CCA, **B.** The Gully, and **C.** The LCA. Accumulating Taxa Count on the y axis and Randomized Coral Locations on the x axis.

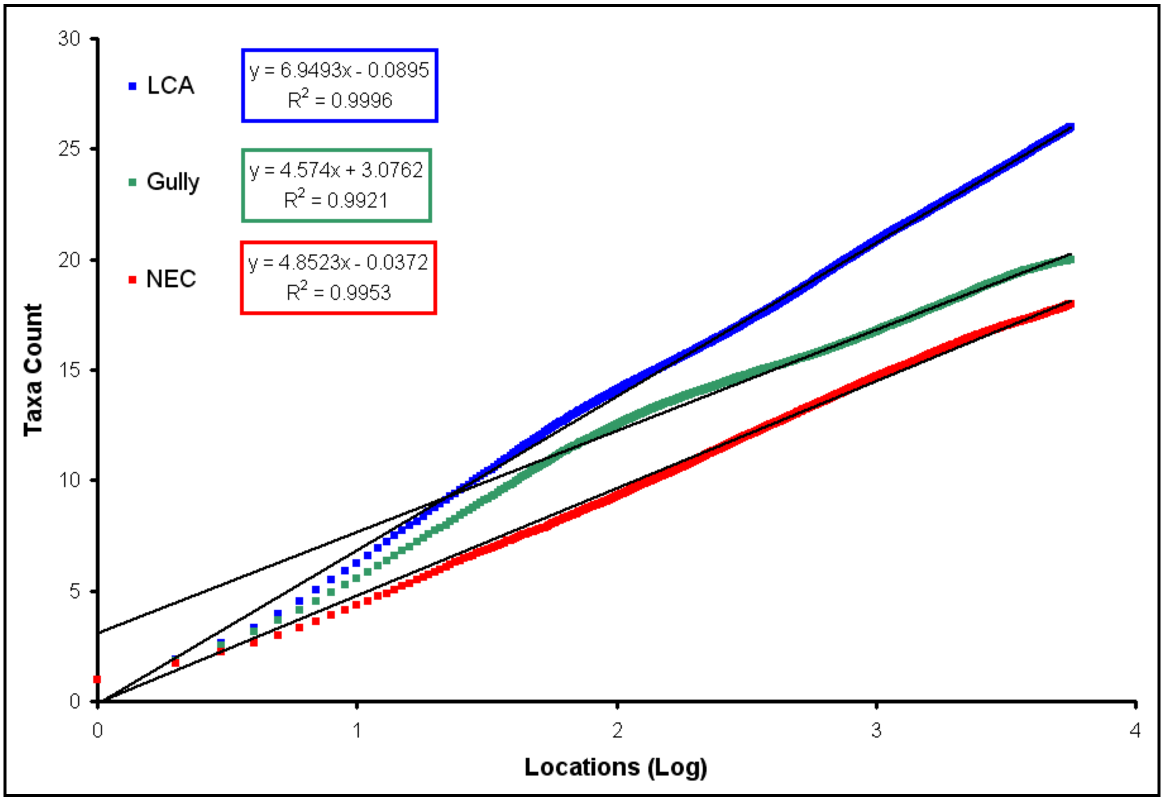


Figure 32. Log transformed Species Accumulation Curves for each protected area.

Protected Area Similarity

Using Primer 6 version 6.1.10, a Bray-Curtis Similarity Matrix was created utilizing the log transformed coral abundance data broken down by buffered protected area (NEC CCA, Gully and LCA) at 500 m intervals. The first step involved running a Cluster Analysis to determine which location and depth combinations taxonomically resemble one another. A Multi-Dimensional Scaling Plot (MDS) was then created and 4 levels of similarity (20, 30, 57 and 66%) were overlaid on the MDS to illustrate the resemblance of each protected area at 500 m depth intervals (Figure 33). The MDS shows a close similarity (>57%) between all protected areas at 500 m, with generally diverging similarity between the NEC CCA and the other 2 protected areas as depth intervals increase.

The rate of taxonomic shift between depth intervals appears more prevalent in the LCA and NEC CCA compared to the Gully. Without understanding the underlying data, this could be misinterpreted to mean that the taxonomic similarity across intervals within the Gully is greater than the other two protected areas. While this may be somewhat true, it is also important to understand that the depth data extracted to each coral location via ArcGIS 9.2 was taken from the General Bathymetric Chart of the Oceans (GEBCO). The GEBCO map used was of only 500 m resolution. During the depth extraction process interpolation was used within a grid cell to approximate depth based on proximal cells, but because of the high slope of the canyon walls and diverse terrain of the Gully, there was more error in assigning depth compared to the relatively flat terrain of either the NEC CCA or the LCA. This means that there would be more taxonomic overlap between intervals, reflective in a smaller relative taxonomic shift with increasing depth compared to the NEC CCA or LCA.

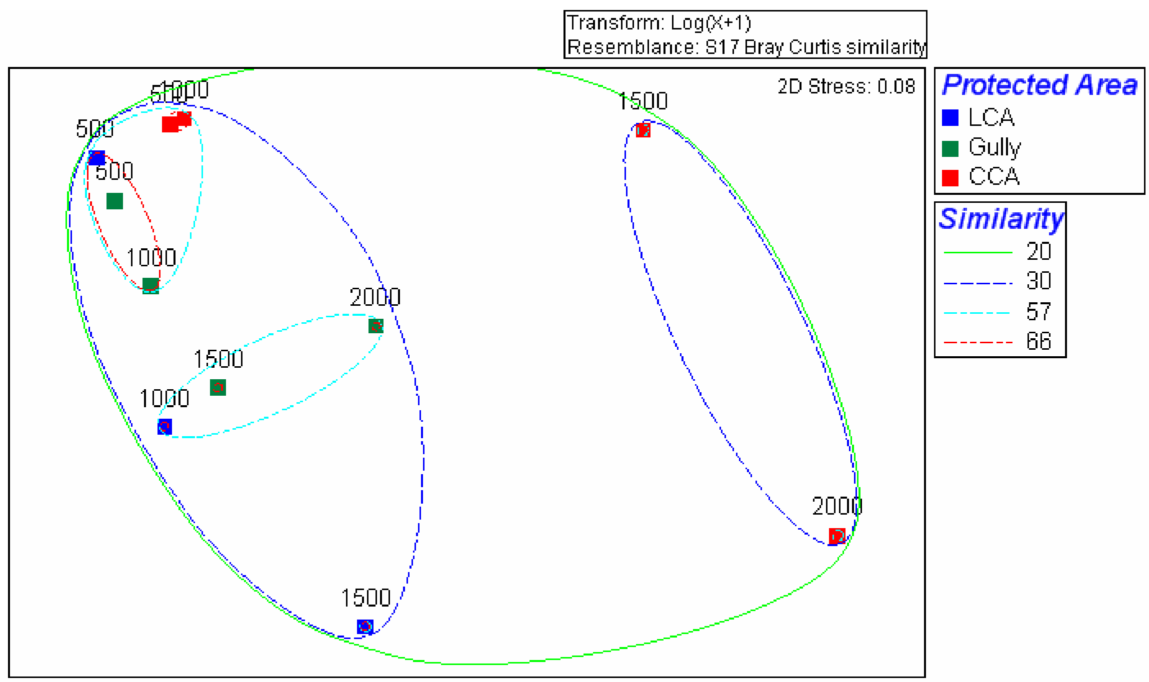


Figure 33. A Multi-Dimensional Scaling Plot derived from a Bray-Curtis Similarity Index comparing coral taxonomic abundance 500 m intervals between areas defined in Figure 30.

A 2-way crossed "Analysis of Similarity" (ANOSIM) with no replicates was performed on the log transformed Bray-Curtis Similarity Matrix with 999 permutations, using **Protected Area** (NEC CCA, Gully, LCA) and **500 m Depth Interval** (500, 1000, 1500, 2000 – where 500 is <500 and 1000 = 501-1000, etc…) as factors. The tests for differences between protected areas across all 500 m depth intervals revealed a Spearman's rank correlation coefficient (ρ) of 0.667 with a significance level (p) of 0.20. The tests for differences between 500 m depth intervals across all protected areas showed a $\rho = 0.776$ which was significant at $p = 0.03$. This suggests that while there is no statistically significant difference between the protected areas across all 500 m depth intervals, there is a significant difference in taxonomic composition between 500 m intervals across all protected areas. Using this information, a 1-way ANOSIM was performed to make pairwise comparisons between 500 m depth intervals. The global ρ was 0.302 and was significant ($p \leq 0.05$) as was the case in the 2-ways analysis. Table 9 displays the pairwise comparisons between each depth. It is clear that the significance of the global test is driven by the pairwise tests comparing the taxonomic similarity between intervals of at least 1000 m apart (groups 2, 5 and 6 – $p \leq 0.1$), whereas the taxonomic differences between adjacent intervals (groups 1, 3, and 4 - p≥0.1) were less significant. However, none of the pairwise tests were significant.

Table 9. Results of pairwise tests from the 1-way ANOSIM of the 500 m depth interval. The global test for differences between 500 m depth intervals across all protected areas showed that the sample statistic (ρ=0.302) was significant (p≤0.05).

Group	Intervals	R Stat	Significance	Possible Permutations	Actual Permutations	Number ≥ Observed
1	1000, 1500	0.185	0.20	10	10	2
2	1000, 2000	0.5	0.10	10	10	1
3	1000, 500	0.037	0.60	10	10	6
4	1500, 2000	-0.25	80	10	10	8
5	1500, 500	0.667	0.10	10	10	1
6	2000, 500	0.75	0.10	10	10	1

The pairwise comparisons shown in Table 9 suggest that because there is no significant taxonomic difference between adjacent 500 m intervals they could be pooled into 1000 m intervals (500 & 1000; 1500 & 2000) and thus act as replicates. Using this pooled data; a 2-way crossed ANOSIM with replicates was performed using **Protected Area** and **1000 m Depth Interval** (1000 and 2000) as factors, with 999 permutations. The global test for differences between protected area across all depth intervals (1000 m and 2000 m) had a sample statistic of ρ=0.901 with a significance level of p≤0.05. Pooling the 500 m intervals into 1000m intervals revealed a significant difference in taxonomic composition between protected areas. However, the pairwise tests between protected areas (Table 10) showed no significant taxonomic difference.

Table 10. Results of pairwise tests from the 2-way ANOSIM with replication of the 1000 m depth interval. The global test for differences between protected area groups across all 1000 m intervals showed that the sample statistic (ρ=0.55) was significant (p≤0.05).

Group	Protected Area	R Stat	Significance	Possible Permutations	Actual Permutations	Number ≥ Observed
1	Gully, LCA	0.511	0.22	9	9	2
2	Gully, CCA	0.875	0.11	9	9	1
3	LCA, CCA	0.674	0.11	9	9	1

To further describe which coral taxa are primarily driving the differences between groups 2, 5 and 6 of Table 9, a 1-way "Similarity Percentages" analysis (SIMPER) was performed on the log transformed taxonomic abundance data using the 500 m interval as the factor. This analysis assesses similarity within each depth interval across protected areas. The cumulative % which each species contributes to similarity was set at 80%. Table 11 shows that the within group similarity across all protected areas declines from a high of 67.2% at 500 m to a low of 26.8% at 2000m. This is further illustrated in Figure 33 which shows that at 500 m there is high similarity across all three protected areas, but with decreasing similarity as depth increases.

Table 11. The average within group similarity and the coral taxa accounting for 80% of the similarity within each 500 m interval resulting from the 1-way SIMPER analysis.

500 m interval – average similarity 67.20%					
Taxa	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Primnoa resedaeformis	6.93	12.49	20.50	18.58	18.58
Paragorgia arborea	5.84	11.03	21.98	16.42	35.00
Anthomastus grandiflorus	5.80	10.53	6.71	15.67	50.68
Nephtheidae F.	5.95	8.27	1.85	12.31	62.99
Keratoisis ornata	4.09	6.55	5.08	9.75	72.74
Acanthogorgia spp.	4.11	5.67	1.56	8.44	81.18
1000 m interval – average similarity 61.10%					
Taxa	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Anthomastus grandiflorus	6.78	9.99	9.74	16.35	16.35
Paragorgia arborea	4.90	7.60	6.48	12.44	28.79
Keratoisis ornata	5.86	7.60	9.01	12.43	41.22
Acanthogorgia spp.	5.05	7.01	23.87	11.48	52.70
Pennatula spp.	5.15	5.98	1.42	9.79	62.49
Primnoa resedaeformis	4.58	5.58	2.31	9.12	71.62
Nephtheidae F.	5.06	3.57	0.86	5.84	77.46
Desmophyllum spp.	4.06	2.89	1.65	4.73	82.19
1500 m interval – average similarity 41.83%					
Taxa	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Radicipes spp.	5.69	11.21	5.45	26.79	26.79
Anthomastus grandiflorus	3.21	5.72	2.92	13.67	40.46
Flabellum spp.	3.75	5.30	4.28	12.68	53.14
Acanella arbuscula	3.40	4.35	1.54	10.39	63.53
Pennatula spp.	3.93	3.68	3.56	8.79	72.32
Kophobelemnon stelliferum	3.64	3.07	0.58	7.34	79.66
Desmophyllum spp.	3.10	2.23	0.58	5.33	84.99
2000 m interval – average similarity 26.81%					
Taxa	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Acanella arbuscula	4.07	9.69	N/A	36.13	36.13
Pennatula spp.	3.12	9.69	N/A	36.13	72.26
Kophobelemnon stelliferum	2.36	4.96	N/A	18.49	90.75

The results from the 1-way SIMPER analysis of 500 m intervals displayed in Table 11, highlights the species dominating each interval. For example, *Primnoa resedaeformis* and *Paragorgia arborea* dominate the first 500 m, accounting for 30% of the similarity in this interval. This analysis also shows that *Anthomastus grandiflorus* has an extensive depth range, between 500 and 1500 m, but its greatest abundance and largest contribution is centered at the 1000m interval where it alone contributes to 16.65% of the average similarity within this interval. *Keratoisis ornata* is also more abundant for both the 500 m and 1000 m interval, but its largest contribution, like *Anthomastus grandiflorus*, is centered at the 1000 m interval. The 1000 m interval is also the strata with the greatest abundance of the sea pens, genus *Pennatula* spp. In the deeper waters of the 1500 and 2000 m intervals, with the exception of *Anthomastus grandiflorus*, a different subset of deep water coral taxa begin to dominate as the primary contributors to similarity. *Radicipes* spp. has a narrow depth range and on its own contributes to over half of the average similarity seen within the 1500 m interval. In the 2000 m interval the coral taxa contributing to 80% of the similarity are reduced, but the dominant coral taxa at this depth is *Acanella arbuscula*.

Pairwise comparisons of groups identified in Table 9 (500, 2000; 500, 1500; 1000, 2000) resulting from the 1-way SIMPER analysis, as well as the coral taxa which contribute most to their dissimilarity, are listed in Table 12. The 1000, 2000 pairwise comparison has an average dissimilarity of 61.61%, with ~30% of the dissimilarity being attributable to just 4 taxa: *Anthomastus grandiflorus, Paragorgia arborea, Keratoisis ornata* and the soft corals of the family Nephtheidae; all taxa more common to the 1000 m interval. The 500, 1500 comparison has an average dissimilarity of 62.2 with 3 coral taxa responsible for ~30% of the total dissimilarity (*Primnoa resedaeformis, Paragorgia arborea* and *Radicipes* spp.), with *P. resedaeformis* and *P. arborea* being abundant in the 500 m interval and *Radicipes* spp. more abundant at 1500 m. An even greater amount of dissimilarity (66.36%) is observed for the pairwise comparison of 500, 2000. The reduced taxonomic overlap between these depth intervals is driven by the emergence of a subset of deep water coral taxa.

Table 12. The average dissimilarity derived from the 1-way SIMPER analysis between depth intervals greater than 500 m apart. The coral taxa contributing to ~30% of the average dissimilarity within the pairwise comparisons are listed.

2000 & 500 m interval - average dissimilarity 66.36 %						
Taxa	**Av.Abund 2000**	**Av.Abund 500**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Primnoa resedaeformis	1.10	6.93	7.79	2.58	11.74	11.74
Paragorgia arborea	0.00	5.84	7.60	5.52	11.46	23.20
Nephtheidae F.	0.55	5.95	7.02	2.01	10.58	33.78
1500 & 500 m interval - average dissimilarity 62.20 %						
Taxa	**AV.Abund 1500**	**Av.Abund 500**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Primnoa resedaeformis	0.60	6.93	7.24	2.71	11.64	11.64
Paragorgia arborea	0.37	5.84	6.21	3.15	9.98	21.62
Radicipes spp.	5.69	1.23	4.80	2.98	7.72	29.34
Nephtheidae F.	3.15	5.95	4.38	1.20	7.05	36.38
1000 & 2000 interval - average dissimilarity 61.61 %						
Taxa	**Av.Abund 1000**	**Av.Abund 2000**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Anthomastus grandiflorus	6.78	1.24	6.39	2.43	10.37	10.37
Paragorgia arborea	4.90	0.00	5.62	3.36	9.12	19.50
Keratoisis ornata	5.86	1.20	5.33	2.05	8.66	28.16
Nephtheidae F.	5.06	0.55	4.68	1.41	7.59	35.75

A 2-way SIMPER analysis using **1000 m interval** and **Protected Area** as factors was also run to describe within group similarity of each protected area and the pairwise comparison between protected areas. The within protected area similarity across both 1000 m intervals shows which species were contributing the most to the similarity between intervals within a protected area. The top 30% of total similarity within each protected area was dominated by species with large depth ranges typically spanning across the 1000 to 1500 m intervals (*Pennatula* spp., *Radicipes* spp., soft corals (family Nephtheidae), *Anthomastus grandiflorus,* and in the NEC CCA - *Acanella arbuscula*) (Table 13).

Table 13. The average similarity derived from a 2-way SIMPER analysis within each protected area across all 1000 m depth intervals. The coral taxa contributing to ~30% of the average similarity within each protected area are listed.

CCA - average similarity 57.98%					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Acanella arbuscula	3.49	15.16	0.79	26.15	26.15
Pennatula spp.	3.49	7.55	2.75	13.02	39.17
Gully - average similarity 67.88 %					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Pennatula spp.	5.98	7.20	2.37	10.61	10.61
Radicipes spp.	4.52	6.96	1.14	10.26	20.87
Nephtheidae F.	5.53	6.73	1.02	9.91	30.78
LCA - average similarity 58.94 %					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Nephtheidae F.	5.98	9.49	N/A	16.10	16.10
Anthomastus grandiflorus	5.22	9.40	N/A	15.95	32.06

The pairwise comparison of protected area dissimilarity results of the 2-way SIMPER analysis (factors – **Protected Areas**, **1000 m Intervals**) shows only a 38.61% taxonomic dissimilarity between the Gully and the LCA (Table 14). The Gully and LCA were both more dissimilar with the CCA, at 51.24% and 50.06% respectively. The combined taxa contributing to at least 30% of the dissimilarity between the Gully and the NEC CCA as well as the LCA and the NEC CCA are Nephtheidae F., Pennatulacea O., *Radicipes* spp., *Acanella arbuscula*, *Keratoisis ornata* and *Kophobelemnon stelliferum.* The taxa Pennatulacea O., *Radicipes spp.*, *Acanella arbuscula*, and *Kophobelemnon stelliferum* are all predominantly deepwater taxa that, with the exception of *Acanella arbuscula,* are more dominant in the Gully and LCA. In shallower water, *Keratoisis ornata* and the soft corals (Nephtheidae F.) are more dominant in the Gully and LCA.

Table 14. The average pairwise protected area dissimilarity derived from the 2-way SIMPER analysis across 1000 m depth intervals. The coral taxa contributing to ~30% of the average dissimilarity within the pairwise comparisons are listed.

Gully & LCA - average dissimilarity 38.61%						
Species	**Av.Abund Gully**	**Av.Abund LCA**	**Av.Diss**	**Diss/SD**	**Contrib %**	**Cum. %**
Pennatula spp.	5.98	1.26	4.11	2.09	10.65	10.65
Funiculina sp.	0.00	2.74	2.51	1.12	6.49	17.15
Kophobelemnon stelliferum	1.89	3.95	2.50	1.08	6.49	23.63
Keratoisis ornata	5.36	3.08	2.37	1.27	6.14	29.78
Desmophyllum spp.	3.13	4.05	2.24	1.60	5.81	35.59
Gully & CCA - average dissimilarity 51.24 %						
Species	**Av.Abund Gully**	**Av.Abund CCA**	**Av.Diss**	**Diss/SD**	**Contrib %**	**Cum. %**
Nephtheidae F.	5.53	0.88	4.94	2.31	9.63	9.63
Pennatulacea O.	4.18	0.00	4.77	2.68	9.30	18.93
Radicipes spp.	4.52	1.03	4.37	1.29	8.52	27.46
Keratoisis ornata	5.36	2.08	3.74	1.81	7.30	34.75
LCA & CCA - average dissimilarity 50.06 %						
Species	**Av.Abund LCA**	**Av.Abund CCA**	**Av.Diss**	**Diss/SD**	**Contrib %**	**Cum. %**
Nephtheidae F.	5.98	0.88	5.34	3.27	10.67	10.67
Radicipes spp.	4.77	1.03	4.84	1.37	9.67	20.34
Acanella arbuscula	3.25	3.49	4.25	1.66	8.49	28.84
Kophobelemnon stelliferum	3.95	1.11	3.95	1.19	7.89	36.72

Similar to the pairwise 500 m SIMPER analysis results (Table 12), the taxa contributing up to 30% of the 58.26% dissimilarity between the 1000 and 2000m intervals are *Primnoa resedaeformis, Paragorgia arborea, Anthomastus grandiflorus, and Acanthogorgia* spp. (Table 15). The only three species more abundant at depth in the 80% contribution to dissimilarity between the 1000 and 2000 m intervals are *Kophobelemnon stelliferum*, *Radicipes* spp., and *Acanella arbuscula*. These were all species identified in Table 14 that highlight a large portion of the dissimilarity between the Gully/LCA and the NEC CCA.

Table 15. The average pairwise 1000 m depth interval dissimilarity derived from the 2-way SIMPER analysis across protected areas. The coral taxa contributing to ~80% of the average dissimilarity within the pairwise comparisons are listed.

1000 & 2000 m interval - Average dissimilarity 58.26						
Species	**Av.Abund 1000**	**Av.Abund 2000**	**Av.Diss**	**Diss/SD**	**Contrib %**	**Cum. %**
Primnoa resedaeformis	5.76	0.80	6.66	1.58	11.44	11.44
Paragorgia arborea	5.37	0.22	6.30	2.46	10.81	22.25
Anthomastus grandiflorus	6.29	2.42	4.51	1.45	7.74	29.99
Acanthogorgia spp.	4.58	1.86	4.16	1.64	7.15	37.14
Keratoisis ornata	4.98	1.82	4.09	1.85	7.02	44.15
Acanella arbuscula	2.50	3.67	3.74	1.29	6.42	50.58
Nephtheidae F.	5.50	2.11	3.33	1.52	5.72	56.30
Radicipes spp.	2.17	4.71	3.21	1.27	5.52	61.81
Paramuricea spp.	2.10	1.41	2.94	1.28	5.05	66.87
Pennatula spp.	3.94	3.60	2.73	1.37	4.69	71.56
Kophobelemnon stelliferum	1.37	3.13	2.59	1.18	4.45	76.01
Desmophyllum spp.	2.79	2.22	2.28	2.31	3.91	79.91
Flabellum spp.	1.39	2.39	1.91	1.21	3.27	83.18

Conclusions

The decline in "within group" similarity seen with increasing 500 m depth intervals (Table 11) across all protected areas shows that there is a greater degree of connectivity between each protected area within the first 1000 m. The pairwise test of dissimilarity between protected areas across 1000 m intervals derived from the 2-way SIMPER (Table 14) further illustrates that not only is there a difference in taxonomic composition between depths across all protected areas, but that this taxonomic difference at depth is what separates the NEC CCA from the other two protected areas. So while all protected areas are taxonomically similar up to 1000 m, at intervals beyond 1000 m the LCA and Gully appear to maintain a greater level of connectivity, while taxonomically diverging from the NEC CCA.

The Gully and LCA are in close proximity (~160 km) and are also connected by a strong southwesterly flow of cool and relatively fresh water originating from the Gulf of St. Lawrence and Newfoundland Shelf along the shelf break (Han *et al.* 1997). Web Drogue version 0.66 (Bedford Institute of Oceanography, Halifax, Nova Scotia, Canada) was used to predict the drift trajectory of particles (e.g., larvae) using circulation data derived from tides, seasonal mean circulation, wind-driven circulation, and surface-wind drift (Hannah *et al.* 2001). This mean flow is consistent through all seasons but is particularly intense during April and May, which coincides with the spring phytoplankton bloom (Harrison *et al.* 2009). The spring shelf break flow does continue in a southwesterly direction from the Gully all the way to the NEC CCA but is highly variable depending on storms and the influence of warm water eddies emerging from the Gulf Stream (John Loder, Pers. Comm.). The majority of the flow from the LCA and Gully between March and June ends up in a anti-clockwise gyre south of both Sable and Western bank (Figure

34). When the spatial extent of the model is focused on the southwestern portion of the Scotian Shelf the theoretical particle placed in the Gully shows a similar trajectory following the southwesterly flow of the shelf break current then heading south and then east when the particle reaches Western Bank (Figure 35). The NEC CCA particle is immediately forced southwest hugging the shelf break and then begins a sharp turn bearing east and then northeast.

Figures 34, 35 and the literature supporting these models, illustrates the connection between the LCA and the Gully and emphasizes the separation in circulation between these sites and the NEC CCA. According to Han (1997), this separation would be amplified when following the trajectory of particles in the deep waters at the base of the shelf break. In the deep water of the LCA and Gully, the southwesterly flow of the shelf break current is less intense than at the surface but also results in an anti-clockwise rotation south of approximately Western or Emerald Bank. At depth this flow is less likely to be disrupted due to surface effects like storms and thus could result in a deep biological boundary between the Eastern and Western portions of the Scotian Slope. This further supports the results that the taxonomic differences seen between the LCA/Gully combination and the CCA are more prevalent in water great than 1000 m in depth. This also suggests that any additional benthic surveys focusing on the deep waters of the NEC CCA would reveal a composition of taxa unique to the NEC CCA.

The shelf break current relating the Gully and the LCA further illustrates their connectedness and underlies the importance of upstream impacts on both areas from factors originating within the Laurentian Channel and all points east along the Scotian Slope. It is hoped that in light of these results, management and monitoring practices can be adjusted to track upstream changes that may ultimately affect the Gully MPA and the LCA.

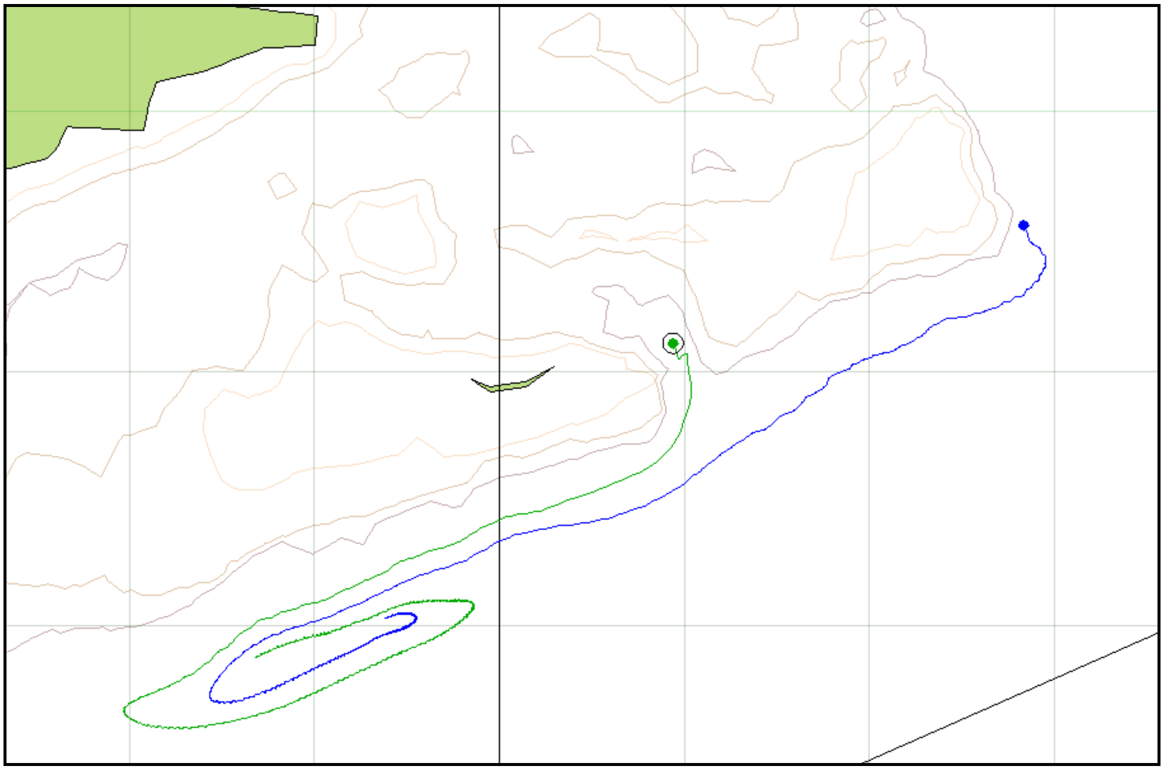


Figure 34. Web Drogue version 0.66 prediction of particle trajectory at 100 m water depth between March 1 and June 1. The LCA in blue and the Gully in Green.

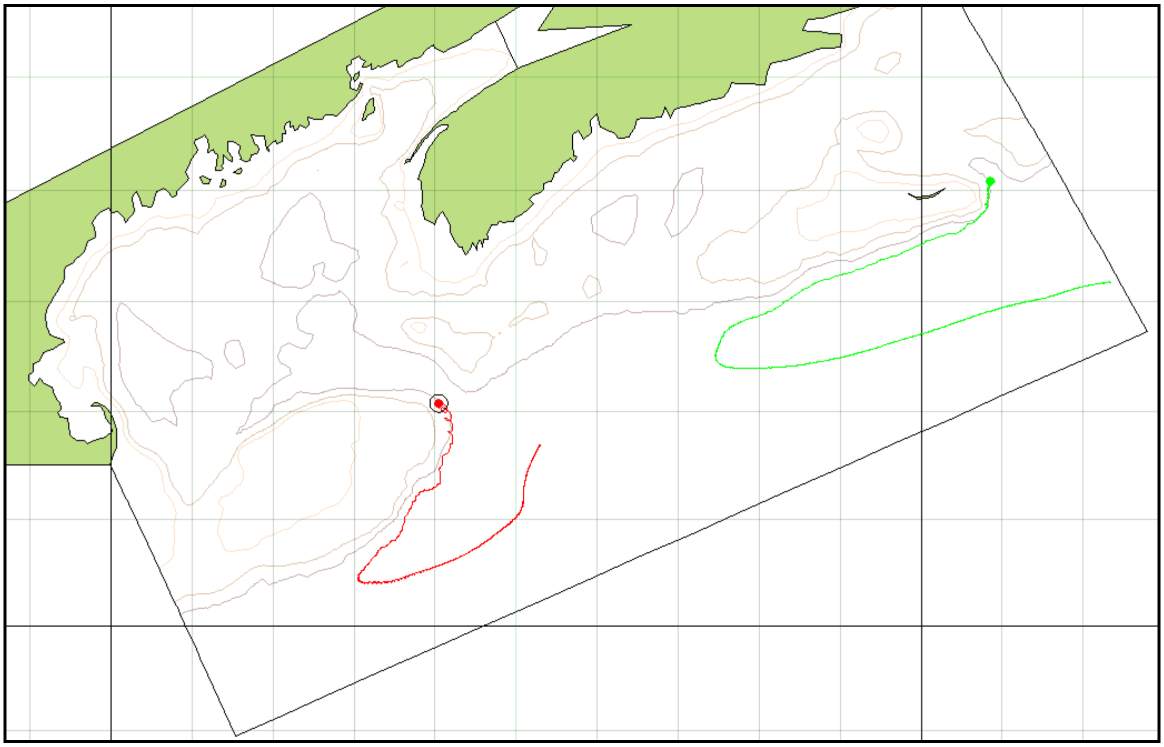


Figure 35. Web Drogue version 0.66 prediction of particle trajectory at 100 m water depth between March 1 and June 1. The NEC CCA in Red and the Gully in Green.

Maritimes Region Coral Database

In an attempt to standardize the process of continually updating coral records in the Maritimes Region, a user friendly Microsoft Access database was created. This database acts as an archival repository for coral records from numerous sources (Table 16) and includes the coordinates for each record in association with many other data fields. The database is structured for use by novice users with limited Microsoft Access experience. Ultimately the database functionality (i.e., data entry, data retrieval, database editing, or in combination) will be tailored to the user depending on their permission level. All data entry (either individual or batch records) and queries are performed through customized query forms created in Access (Figures 36 & 37). To retrieve data for analysis and/or projection in a GIS (Figure 37), the user can select fields and/or filter the fields for specified information within that field and in any combination with other fields (e.g., a year, specific gear, region, mission, taxa, etc…). Once the user has selected the information they wish to extract from the master database, they can export the data to a Comma Separated Values (*.CSV) file or access data table which can then be used to plot x/y coordinates in a GIS. A user manual is currently in development and this database has already seen regular use by the Benthic Ecology Group at BIO.

The inception of the database was as a result of cruise planning purposes for regional benthic surveys. Recently however, there have been numerous requests for Maritime coral distribution records from a variety of users within DFO and internationally. In fact, the database is currently in use by the DFO Oceans Branch Centre of Expertise for Corals and Sponges (Northwest Atlantic Fisheries Centre, St. John's, Newfoundland) to develop layers for their online Coral Atlas.

The database is structured in such a way that records from other taxonomic groups could be added in the future. In addition, much time has been spent discussing ways that components of this database may integrate with large existing databases (i.e., OBIS and BIOCHEM) which currently contain little benthic fauna distribution data. The funding for this initiative was largely procured through the International Governance Strategy. For the time the database is under the supervision of the Benthic Ecology Group. This maintains the integrity of the database and simultaneously limits the dissemination of data that has not been fully vouchered.

Table 16. A synopsis of Maritime coral distribution data source.

Source	**Survey Type**	**Gear**	**Error**	**Records**	**%** †
CAMPOD	Benthic	Drop Camera	≤ 100 m	62422	56.37
ROPOS	Benthic	ROV	≤ 100 m	39040	35.26
DFO Groundfish Surveys (null records)*	Trawl	Western IIA	≥1 km	7065	6.38
DFO Groundfish Surveys (bycatch)	Trawl	Western IIA	≥1 km	1327	1.20
Maritimes Observer Program	Observer Reports	Fishing	Variable	358	0.32
TEK/LEK	N/A	Variable	Variable	284	0.26
DSIS	Benthic Survey	ROV	≤ 100 m	222	0.20

* These records describe where a taxa has not been observed by Groundfish Surveys.

† % of total coral records is calculated from the total Maritime records from the following taxonomic orders as recognized by the European Register of Marine Species (ERMS) – http://www.marbef.org/data/erms.php: Antipatharia, Alcyonacea, Gorgonacea, Pennatulacea and Scleractinia.

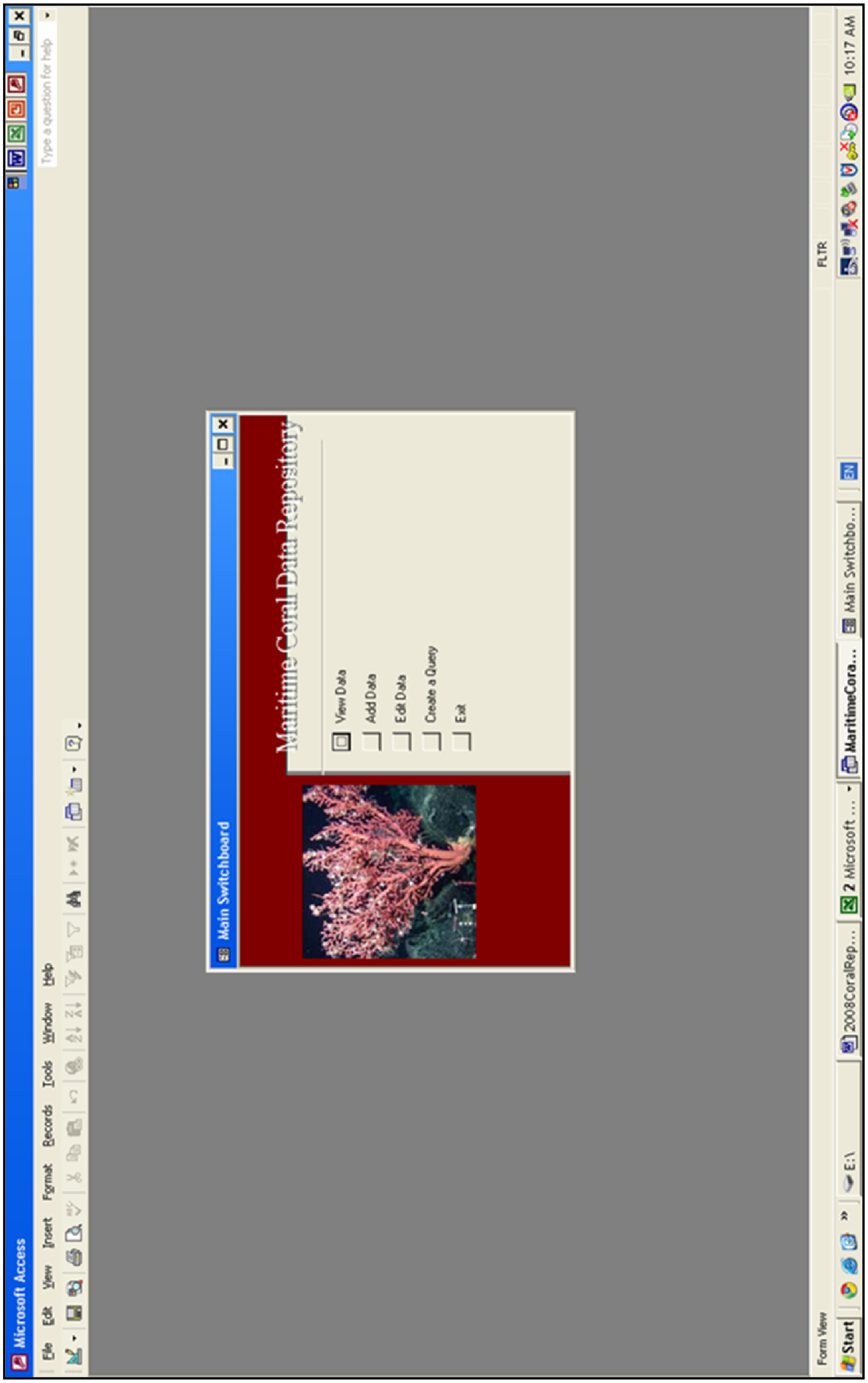


Figure 36. The main switchboard to the Maritimes Coral Data Repository. Note the options, View Data, Add Data, Edit Data, and Create a Query.

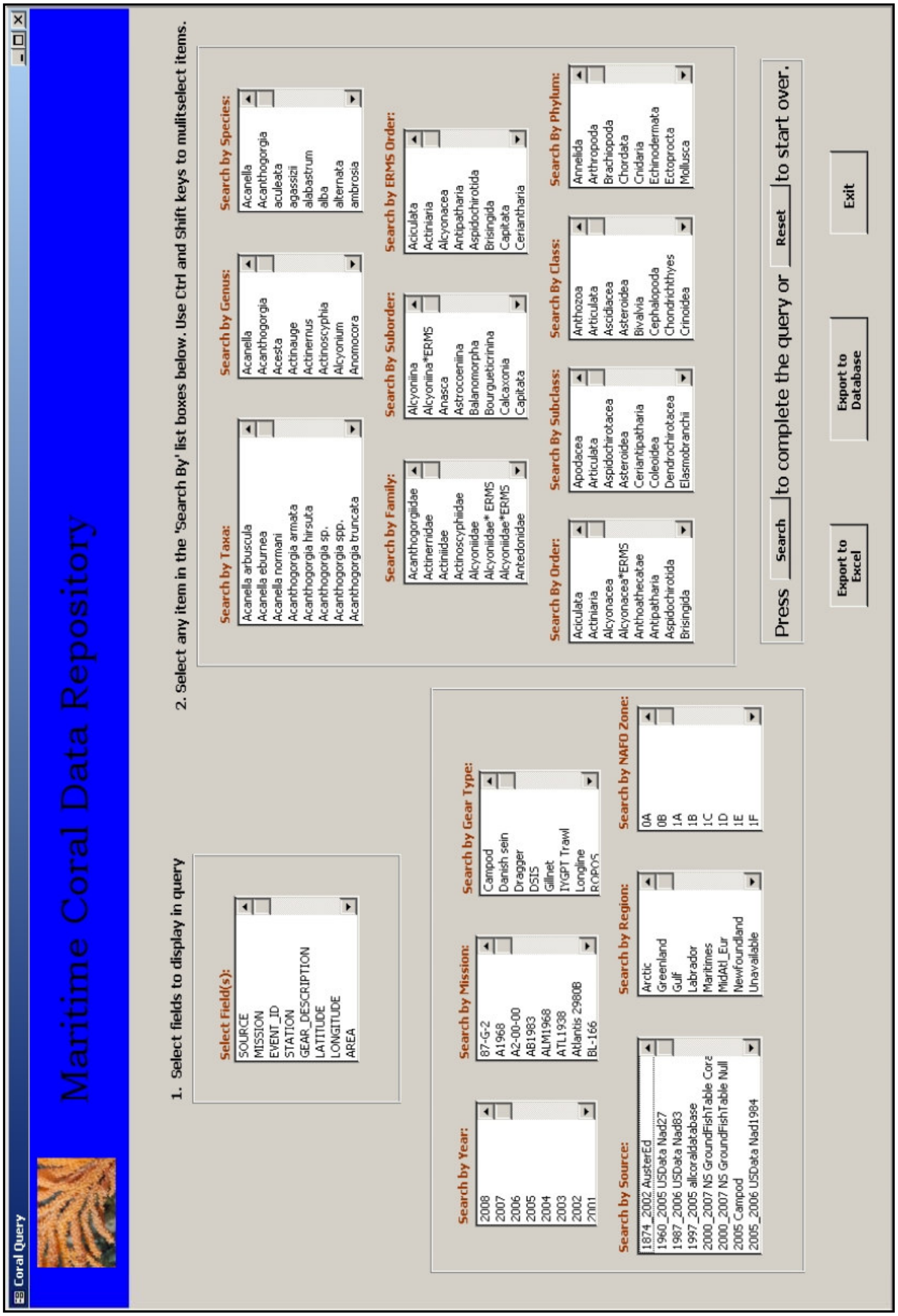


Figure 37. Screen capture of the form query page in the custom designed database. This database gives you the ability to select the fields you wish to display, filter each field by its contents or taxonomic rank.

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