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Deep-Water Corals In Atlantic Canada: A Summary Of ESRF-Funded Research (2001-2003)

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DEEP-WATER CORALS IN ATLANTIC CANADA:

A SUMMARY OF ESRF-FUNDED RESEARCH (2001-2003)

Pål B. Mortensen[1], Lene Buhl-Mortensen[1], Susan E. Gass[2],
Donald C. Gordon Jr., Ellen L.R. Kenchington,
Cynthia Bourbonnais and Kevin G. MacIsaac

Department of Fisheries and Oceans
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, NS, B2Y 4A2

Present Addresses:

[1] Institute of Marine Research, P.O. Box 1870, Nordnes, N-5817, Bergen, Norway

[2] Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, Oban, Argyll, PA37 1QA, UK

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report provides a summary of research on deep-water corals and their habitats off Atlantic Canada which was carried out by the Department of Fisheries and Oceans (DFO) at the Bedford Institute of Oceanography during 2001-2003. This project was funded in part by the Environmental Studies Research Fund (ESRF) and covered different aspects such as distribution, abundance, growth, habitat and biology of deep-water corals and their associated fauna.

Deep-water corals are common in certain areas in Atlantic Canada. Most of the available data prior to this study were anecdotal in nature and based primarily on fishing bycatch information. Four major groups of deep-water corals occur: Alcyonacea (soft corals), Gorgonacea (horny corals), Scleractinia (stony corals), and Antipatharia (black corals). Deep-water corals are mainly found below about 200 m along the edge of the continental slope, in canyons or in channels between fishing banks. However, some soft corals are common in shallower waters on the continental shelf.

During this project, data and samples were obtained from DFO groundfish surveys conducted throughout Atlantic Canada, the Fisheries Observer Program, interviews with fishers, and four dedicated research cruises using DFO research vessels which visited the Northeast Channel, Scotian Slope, the Gully, the Laurentian Channel, and the southern edge of the Grand Banks. The dedicated research cruises relied heavily on the use of video imagery to document the distribution, abundance and condition of deep-water corals.

Video observations were made along 195 transects which totalled 118 km in length. Twenty-three coral taxa were collected or observed, including a new species for the area (the antipatharian black coral *Bathypathes arctica*). Except for the solitary scleractinian cup corals (*Flabellum* spp.), all of these taxa are colonial. The cup corals occurred in patches having much greater abundance than colonial corals, especially along the Scotian Slope and in the Gully. The highest abundance of colonial corals was found in the Northeast Channel while the greatest diversity was found in the Gully. The results confirm earlier suggestions of the Northeast Channel, the Gully and the Stone Fence as prime habitats for colonial corals. They also demonstrate that corals are locally abundant off Newfoundland and Labrador and extend at least as far north as the Davis Straits. Based on records from the observer program, the area off Cape Chidley could be another prime habitat for deep-water corals. The first documented *Lophelia pertusa* reef complex in Atlantic Canada was found near the Stone Fence in the mouth of the Laurentian Channel. This is the only known deep-water coral reef structure in Atlantic Canada.

The distribution of deep-water corals is patchy and influenced by several environmental factors including substrate, temperature, salinity and currents. The substrate largely determines which species can occur. Gorgonians are most common on cobble and boulder, but some species (e.g. *Acanella arbuscula* and *Radicipes* spp.) have anchorage structures for attachment in soft sediments. *Flabellum* spp. grow unattached on finer

sediments. All other scleractinians recorded from the area need a hard substrate for attachment. This study documented that high temperatures restrict the upper depth range of corals with different tolerances for different species. Gorgonian corals are more abundant on the western side of the Northeast Channel, the Gully and the Laurentian Channel, presumably due to a combination of favourable environmental factors including higher concentrations of food particles in outflowing water.

New information on the morphology and growth of gorgonians was collected. The average height of *Paragorgia arborea* colonies observed, 57 cm (range of 5 to 180 cm), was greater than that of *Primnoa resedaeformis* colonies which was 30 cm (range 5 to 86 cm). The height of *P. arborea* colonies was positively correlated to the size of the boulders to which they were attached. *P. arborea* was observed to occur in three colour varieties: salmon, red and white. Most *P. arborea* colonies larger than 50 cm were concave-shaped and oriented into the prevailing current. *P. resedaeformis* had a more irregular morphology and seems to be adapted to turbulent near bottom currents while *P. arborea* seems more adapted to uni- or bi-directional currents higher off the seabed. The average growth rate of *P. resedaeformis* was estimated to 1.7 cm/year while that of *P. arborea* seems to be in the range of 1 to 4 cm/year. At these growth rates, the largest *P. resedaeformis* colony observed was about 61 years old while the largest *P. arborea* colony was between 45 and 180 years old.

Live specimens of *Flabellum alabastrum*, *Duva florida*, *Anthomastus grandiflorus*, *Primnoa resedaeformis*, *Keratoisis ornata*, *Acanella arbuscula*, *Acanthogorgia armata*, and *Paragorgia arborea* were maintained with various levels of success in the BIO Fish Laboratory and used for various studies.

Deep-water corals represent a variety of habitats for other organisms. *Paragorgia arborea* and *Primnoa resedaeformis* host a rich associated fauna dominated by suspension feeders that use the coral colonies as a substratum or refuge against predators. One hundred and fourteen associated invertebrate species were found in this study. This number is smaller than for reef-building deep-water corals, but is comparable with tropical gorgonian corals. Several new species for the area were recorded and two crustacean species were new to science. A few highly specialized parasites have been identified for both coral species. One of these, a parasitic copepod, constitutes the new genus *Gorgonophilus*. The fauna composition differs for the two gorgonians but consists mainly of species also occurring in surrounding habitats. The abundance and diversity of associated fauna is significantly correlated to host morphology. Coral samples collected by ROV or Videograb had more associated fauna than samples collected as bycatch in fishing gear because the latter are subjected to significant washout. Quite a few species of fish were observed together with deep-water corals, the most abundant being redfish.

The most extensive damage from fishing gear was observed at the Stone Fence. The *Lophelia pertusa* reef complex was heavily impacted. Live colonies were either small or clearly broken in an unnatural way. The rubble zone normally surrounding a *L. pertusa* reef was larger than observed at similar sized reefs off Norway. Gorgonians also showed signs of disturbance, namely broken colonies, small size and unnatural occurrence on the sides of and underneath boulders. Many cobbles and boulders were clearly overturned. A fragment of a trawl net was also found. Analysis of fisheries observer data of fishing effort indicates that the general area of the *L. pertusa* reef complex has been heavily trawled annually between 1980 and 2003. Current fisheries operating in the area are otter trawling for redfish and anchored longlines for halibut.

A lower level of fishing damage was observed in the Northeast Channel. In total, 4% of the observed gorgonian colonies were damaged, and broken or tilted corals were observed on 29% of the transects. Lost longlines were observed loose on the seabed or entangled in corals on 37% of the transects. Tracks on the seabed, either from longline anchors or parts of otter trawl gear, were present along three transects, while lost gillnets were observed along two transects. Analysis of effort data indicates that longline activity is widespread throughout the Channel while otter trawling and gillnet activity are concentrated on the Georges Bank side.

Very few indications of fisheries damage to corals were observed in the Gully, just a few trawl tracks and one corroded lost wire from a trawl. The surveyed region along the Scotian Slope has been heavily fished in recent years. However, due to the absence of large colonial corals, no signs of fisheries damage were observed.

The results of this project have been used by DFO to create three conservation areas to protect deep-water corals from further damage and allow recovery. A 424 km^2 coral conservation area was established in the Northeast Channel in 2002. The 2364 km^2 Marine Protected Area was formally declared in the Gully in 2004. And finally, a 15 km^2 coral conservation area centred over the *Lophelia pertusa* reef complex near the Stone Fence in the mouth of the Laurentian Channel was created in 2004.

Information on deep-water corals below 500 m continues to be very sparse in Atlantic Canada because of the depth limits of our sampling gear. Corals extend much deeper and direct observations deeper than 500 m remain a high research priority. Factors controlling the lower depth limit of corals are poorly known but low temperatures and low concentrations of food particles are likely important factors.

This project would not have been conducted without the financial support of the oil and gas industry through the ESRF. Deep-water corals have become an important environmental issue in Atlantic Canada and, as offshore exploration activities move into their habitat, it is important to have sound scientific information on their occurrence and biology. This project has provided new data on their distribution, habitat, associated species, morphology, and growth rate. Such information, which has been reported in the peer-reviewed scientific literature, can be used by the offshore petroleum boards and government departments to minimize the impacts of human activities on these sensitive organisms and their deep-water habitats off Atlantic Canada.

SOMMAIRE

Le présent rapport fournit un sommaire de la recherche sur les coraux abyssaux et leurs habitats au large des côtes du Canada atlantique menée par le ministère des Pêches et des Océans (MPO) à l'Institut océanographique de Bedford (IOB) de 2001 à 2003. Ce projet a été financé en partie par le Fonds pour l'étude de l'environnement (FÉE) et a porté sur différents aspects des coraux abyssaux et des espèces qui leurs sont associées (p. ex. leur répartition, leur abondance, leur croissance, leur habitat et leur biologie).

Les coraux abyssaux sont communs dans certains secteurs du Canada atlantique. La plupart des données disponibles avant la présente étude étaient de nature anecdotique et fondées principalement sur des données sur les prises accessoires lors d'activités de pêche. Il existe quatre principaux groupes de coraux abyssaux : *Alcyonacea* (coraux mous), *Gorgonacea* (coraux cornés), *Scleractinia* (coraux durs) et *Antipatharia* (coraux noirs). Les coraux abyssaux peuvent être observés principalement à des profondeurs supérieures à environ 200 m le long du bord du talus continental, dans des canyons ou dans des chenaux entre les bancs de pêche. Certains coraux mous sont cependant communs dans des eaux moins profondes sur le plateau continental.

Au cours du présent projet, des données et des échantillons ont été obtenus de relevés sur les poissons de fond menés par le MPO dans l'ensemble du Canada atlantique, de même que par le biais du Programme des observateurs des pêches, d'entrevues avec des pêcheurs et de quatre croisières de recherche, au cours desquelles des navires du MPO ont visité le chenal Nord-Est, le talus néo-écossais, le Goulet, le chenal Laurentien et la partie méridionale des Grands Bancs. Lors de ces croisières, une grande importance a été accordée à l'utilisation de l'imagerie vidéo pour étudier la répartition, l'abondance et l'état des coraux abyssaux.

Des enregistrements vidéo ont été réalisés le long de 195 transects d'une longueur totale de 118 km. Vingt-trois taxons de coraux ont été recueillis ou observés, y compris une espèce observée pour la première fois dans le secteur (le corail noir *Bathypathes arctica*, de l'ordre *Antipatharia*). À l'exception des madréporaires solitaires (*Flabellum* spp.; ordre *Scleractinia*), tous ces taxons sont coloniaux. La répartition des madréporaires est éparse, mais ceux-ci sont beaucoup plus abondants que les coraux coloniaux, particulièrement le long du talus néo-écossais et dans le Goulet. Le plus grand nombre de coraux coloniaux a été observé dans le chenal Nord-Est, tandis que la plus grande diversité de ces coraux a été observée dans le Goulet. Les résultats confirment les suggestions antérieures à l'effet que le chenal Nord-Est, le Goulet et le secteur de Stone Fence constituent des habitats de grande qualité pour les coraux coloniaux. Ils montrent également que les coraux sont abondants par endroits au large de Terre-Neuve-et-Labrador et que la limite nord de leur aire de répartition est située au moins à la hauteur du détroit de Davis. Selon les registres établis dans le cadre du Programme des observateurs des pêches, le secteur au large du cap Chidley pourrait constituer un autre habitat de grande qualité pour les coraux abyssaux. Le premier récif de *Lophelia pertusa* découvert au Canada atlantique est situé à proximité du secteur de

Stone Fence, à l'embouchure du chenal Laurentien. Il s'agit du seul récif de coraux abyssaux connu au Canada atlantique.

La distribution des coraux abyssaux est éparse et dépend de plusieurs facteurs environnementaux incluant le substrat, la température, la salinité et les courants, le substrat constituant un facteur particulièrement important. Les coraux cornés sont observés le plus souvent sur des galets ou des blocs, mais certaines espèces (p. ex. *Acanella arbuscula* et *Radicipes* spp.) sont dotées de structures d'ancrage aux fins de fixation dans des sédiments mous. Les madréporaires solitaires croissent dans des sédiments plus fins sans y être fixés. Tous les autres coraux durs observés dans le secteur ne se fixent qu'à des substrats durs. Cette étude a montré que la température (notamment les températures élevées) influent sur la limite supérieure de profondeur de la zone de répartition des coraux, chaque espèce ayant un niveau de tolérance qui lui est propre. Les coraux cornés sont plus abondants sur le côté ouest du chenal Nord-Est, du Goulet et du chenal Laurentien, probablement en raison d'une combinaison de facteurs environnementaux favorables, y compris des concentrations plus élevées de particules alimentaires dans l'eau sortante.

De nouvelles données sur la morphologie et la croissance des coraux cornés ont été recueillies. La hauteur moyenne des colonies de *Paragorgia arborea* observées est de 57 cm (hauteur variant entre 5 et 180 cm) et donc supérieure à celle des colonies de *Primnoa resedaeformis* observées (30 cm et variant entre 5 et 86 cm). Il existe une corrélation positive entre la hauteur des colonies de *P. arborea* et la taille des blocs auxquels elles sont fixées. Trois variétés de couleurs de *P. arborea* ont été observées : saumon, rouge et blanc. La plupart des colonies de *P. arborea* de plus de 50 cm avaient une forme concave et étaient orientées dans le sens du courant dominant. *P. resedaeformis* a une forme moins régulière et semble adaptée aux courants turbulents près du fond, tandis que *P. arborea* semble mieux adaptée aux courants unidirectionnels et bidirectionnels plus loin du fond. Le taux de croissance moyen de *P. resedaeformis* est estimé à 1,7 cm/année, tandis que celui de *P. arborea* semble varié de 1 à 4 cm/année. D'après ces taux, la plus grande colonie de *P. resedaeformis* observée avait environ 61 ans, tandis que la plus grande colonie de *P. arborea* avait entre 45 et 180 ans.

Des spécimens de *Flabellum alabastrum*, *Duva florida*, *Anthomastus grandiflorus*, *Primnoa resedaeformis*, *Keratoisis ornata*, *Acanella arbuscula*, *Acanthogorgia armata* et *Paragorgia arborea* ont été conservés vivants au Laboratoire des poissons de l'IOB, avec divers niveaux de succès, et utilisés dans diverses études.

Les coraux abyssaux constituent une variété d'habitats pour d'autres organismes. *P. arborea* et *P. resedaeformis* sont les hôtes d'une riche faune associée qui est dominée par des suspensivores utilisant les colonies coralliennes comme substrat ou comme refuge contre les prédateurs. Au cours de la présente étude, 114 espèces d'invertébrés ont été recensées comme étant en association avec les deux espèces de coraux. Ce nombre est inférieur à celui pour les récifs de coraux abyssaux, mais semblable à celui pour les coraux cornés tropicaux. Plusieurs espèces ont été observées pour la première fois dans le secteur, et deux espèces de crustacés ont été découvertes. Quelques parasites très spécialisés ont été signalés chez les deux espèces de coraux. Un de ceux-ci, un copépode, constitue le nouveau genre *Gorgonophilus*. La faune associée diffère entre les deux espèces de coraux cornés, mais elle consiste principalement en des espèces qui sont également présentes dans les habitats avoisinants. Il existe une grande corrélation entre l'abondance et la diversité de la faune associée et la morphologie de l'hôte. Davantage d'espèces étaient associées aux échantillons de coraux prélevés à l'aide d'engins télécommandés ou de Videograb qu'aux échantillons pris accidentellement dans des engins de pêche. Ce résultat s'explique par le fait que les prises accessoires de coraux sont soumises à un important lavage. Un bon nombre d'espèces de poissons ont été observées en association avec les coraux abyssaux, la plus abondante étant le sébaste.

Les plus importants dommages causés par des engins de pêche ont été observés dans le secteur de Stone Fence. Le récif de *L. pertusa* a été grandement touché, les colonies vivantes étant soit petites, soit nettement abîmées de manière non naturelle. La zone de gravats habituellement en périphérie des récifs de *L. pertusa* était plus étendue que dans le cas des récifs de taille semblable observés au large de la Norvège. Des signes de perturbation ont également été notés chez des colonies de coraux cornés, nommément des colonies abîmées, des colonies de petite taille et des coraux présents en des endroits non naturels comme sur les côtés ou le dessous de blocs. Un grand nombre de galets et de blocs présentaient des signes de retournement. Un fragment de chalut a été observé. L'analyse des données sur l'effort de pêche consignées par les observateurs des pêches révèle que le secteur du récif de *L. pertusa* a fait l'objet d'un grand nombre de traits de chalut à chaque année entre 1980 et 2003. Les pêches menées actuellement dans le secteur sont la pêche du sébaste au chalut à panneaux et la pêche du flétan à la palangre ancrée.

Des dommages moins importants ont été observés dans le chenal Nord-Est. Au total, 4 % des colonies de coraux cornés observées étaient endommagées, et des coraux abîmés ou inclinés ont été observés sur 29 % des transects. Des palangres perdues ont été observées gisant lâchement sur le fond marin ou emmêlées aux coraux sur 37 % des transects. Des traces laissées sur le fond par des ancres de palangres ou par des parties de chaluts à panneaux ont été observées sur trois transects, et des filets maillants perdus ont été observés sur deux transects. L'analyse des données sur l'effort révèle que des activités de pêche à la palangre sont menées dans l'ensemble du chenal, tandis que les activités de pêche au chalut à panneaux et au filet maillant ont lieu principalement du côté du banc Georges.

De très rares signes de dommages attribuables à la pêche ont été observés dans le Goulet : seules quelques traces de chalut et un câble de chalut corrodé perdu. Au cours des dernières années, un grand nombre d'activités de pêche ont été menées dans la région surveillée le long du talus néo-écossais. Cependant, en raison de l'absence de grandes colonies coralliennes, aucun signe de dommages attribuables à la pêche n'a été observé.

Les résultats du présent projet ont été utilisés par le MPO pour créer trois zones de conservation afin de protéger les coraux abyssaux contre les dommages et de permettre leur rétablissement. Une zone de conservation de 424 km^2 a été créée dans le chenal Nord-Est en 2002. La zone marine protégée de 2 364 km^2 dans le Goulet a été officiellement établie en 2004. Finalement, une zone de conservation de 15 km^2, centrée sur le récif de *L. pertusa*, a été créée en 2004.

En raison des limites des appareils d'échantillonnage, il n'existe encore que très peu de données sur les coraux abyssaux qui croissent à plus de 500 m de profondeur au Canada atlantique. Des coraux sont présents à des profondeurs beaucoup plus grandes, et la possibilité d'effectuer des observations directes à plus de 500 m de profondeur demeure un domaine de recherche hautement prioritaire. Les facteurs qui influent sur la limite inférieure de profondeur de la zone de répartition des coraux sont très peu connus, mais les basses températures et les faibles concentrations de particules alimentaires constituent probablement des facteurs importants.

Le projet n'aurait pu être mené à bonne fin sans l'aide financière de l'industrie pétrolière et gazière, obtenue par l'entremise du Fonds pour l'étude de l'environnement. La question environnementale des coraux abyssaux a pris une grande importance dans le Canada atlantique. Plus les activités d'exploration du sous-sol de la mer progressent vers l'habitat de ces coraux, plus il est critique d'avoir en main des données scientifiques exactes sur leur présence et leur biologie. Le projet a permis d'obtenir de nouvelles données quant à leur répartition, leur habitat, les espèces qui leur sont associées, leur morphologie et leur taux de croissance. Il s'agit d'une information précieuse, dont font mention des ouvrages scientifiques évalués par les pairs et qui peut aider les offices des hydrocarbures extracôtiers et les ministères gouvernementaux à réduire au maximum l'impact des activités humaines sur de tels organismes sensibles et leur habitat en eaux profondes, au large des côtes du Canada atlantique.

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INTRODUCTION

Deep-water corals are found around the world at depths mainly on the order of 200-1500 m and are important components of deep-water ecosystems. While their existence has been known for over 200 years, they have received very little scientific attention compared to their shallow-water relatives, in large part because of the logistic difficulties in studying them. However, with the recent development of technologies such as ROVs and video platforms, it is now possible to study deep-water corals in their natural habitat. As a result, knowledge of deep-water corals is currently growing rapidly around the world.

Deep-water corals display a wide variety of shapes, sizes and colours. More than 700 species occur world-wide. There are four major taxonomic groups: Alcyonacea (soft corals), Gorgonacea (horny corals), Scleractinia (stony corals), and Antipatharia (black corals). Pennatulacea (seapens) are closely related but not regarded as corals by most scientists. Most corals grow attached to stable substrate (e.g. cobbles, boulders, bedrock) while some are anchored in finer sediments or are free-living. All corals are epibenthic and most have an arborescent growth form. Some gorgonian colonies can attain heights of over 3 m. Certain species of stony corals can form reefs that can be many meters high and extend horizontally for more than a kilometer. Deep-water corals are adapted to live without light and at relatively low temperatures. They feed by capturing microscopic organisms and/or organic particles from the surrounding water (Freiwald 1998; Mortensen and Rapp 1998). Growth rates are low and colonies can be hundreds of years old (Wilson 1979; Risk et al. 2002).

Deep-water corals have recently captured public attention and form popular displays in aquariums around the world (i.e. Japan, Norway, Sweden, USA) . Canada Post issued a series of postage stamps depicting corals in 2002. However, from a scientific perspective they have more value than as a “curiosity” species. Biodiversity is higher in and around deep-water corals compared to adjacent areas (Mortensen et al. 1995). They provide shelter and feeding places for a wide variety of invertebrates and fish (Jensen and Frederiksen 1992, Mortensen et al. 1995, Rogers 1999). It has also been suggested that they serve as spawning and nursery sites for some species (Fosså et al 2002, Reed 2002), but this has yet only been demonstrated for juvenile snowy grouper (*Epinephelus niveatus*) (Reed 2002). Additionally, the impressive ages documented for some colonies and the calcified accretions of their skeletons make them valuable for paleoclimatic studies (Smith et al. 1997, Mortensen and Rapp 1998, Heikoop et al. 2002).

Unfortunately, deep-water corals are highly vulnerable to human activities, in particular fishing. Offshore hydrocarbon exploration and development activities have also raised concerns. Fishing with bottom-tending gears has been going on for many years. While the focus of most concern is on trawling, it is recognized that other gear types such as gillnets, longlines and traps can also cause damage (as evidenced by bycatch). There is considerable debate about the extent of past damage and the relative impacts of different gear types, but the risks are clearly increasing as fishing effort moves into deeper water where most corals are more common. Offshore hydrocarbon exploration and development are more recent offshore activities but the potential risks to corals are also increasing as exploration moves into deeper water. There is a strong international conservation movement for the protection of deep-water corals with calls for closed areas and bans on certain gear types.

Deep-water corals are common in certain areas of Atlantic Canada. Early scientific reports include Verrill (1922) and Deichmann (1936). Using all available information which included the scientific literature, museum collections and reports from the fishers, Breeze et al. (1997) reviewed the distribution and status of corals off Nova Scotia and reported 35 species, including 7 soft corals, 10 horny corals, 10 stony corals, and 8 seapens. Five of these species had not been observed in Atlantic Canada but were thought to occur. Most of the limited information available was anecdotal in nature and based primarily on observations of bycatch made by the fishing industry. With the exception of soft corals, which can also be found on the relatively shallow tops of fishing banks, most deep-water corals off Nova Scotia appear to occur at depths between 200-1500 m along the edge of the continental shelf, in submarine canyons, and in channels between fishing banks. Prime locations identified to date include the Northeast Channel, the Gully and the Stone Fence. The review of Breeze et al. (1997) was restricted to the area off Nova Scotia. However, it is suspected that the edge of the Grand Banks, the edge of the Labrador Shelf, the Flemish Cap and Orphan Knoll could also be important deep-water coral sites. For example, dead specimens of the stony coral *Desmophyllum dianthus* (syn. *cristagalli*) have been dredged from the top of Orphan Knoll (Smith et al. 1997).

The Department of Fisheries and Oceans (DFO) must consider deep-water corals in fisheries, habitat and ocean management decisions. Because of the rudimentary nature of current knowledge on deep-water corals and their habitats in Atlantic Canada, it is necessary to collect new information in order to make informed management decisions regarding their need for protection from human activities. More information is needed on the distribution, abundance, biology, and condition of deep-water corals in all three oceans bordering Canada.

To this end, in 1997, DFO began to collect video and photographic information of deep-water corals on an opportunity basis at prime sites off Nova Scotia including the Northeast Channel, the Gully and the Stone Fence (Fig. 1).

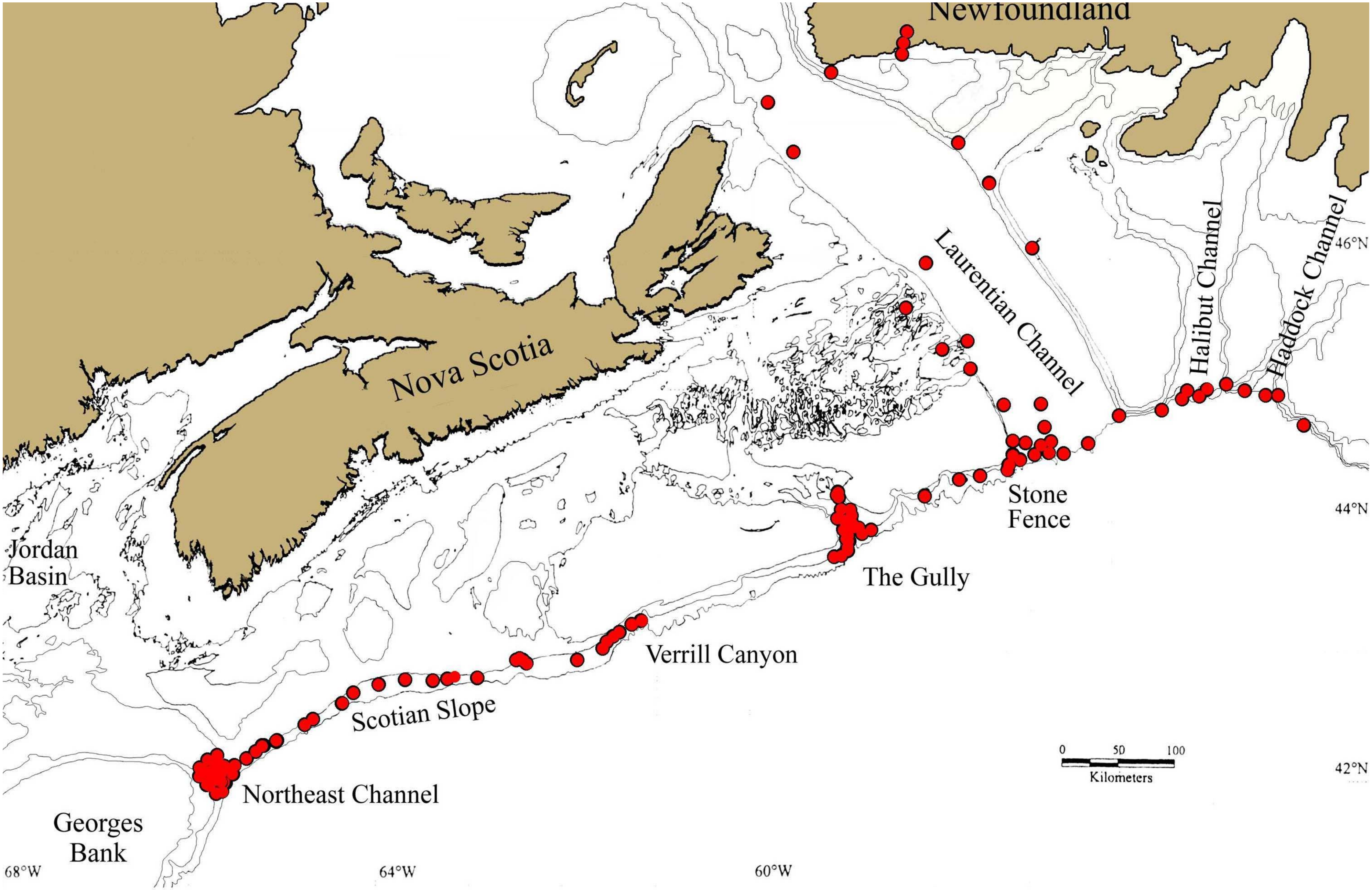

Figure 1. The location of sites in Atlantic Canada where video transects targeting deep-water corals were carried out using Campod (185 sites) or ROPOS (10 sites) (1997-2002). Individual sites can not be resolved at this scale in heavily sampled regions (i.e. Northeast Channel, the Gully and Stone Fence).

This initial work was done during cruises funded for the mobile gear impact and Gully programs (1997-2000). A start was also made to capture information on deep-water corals collected as bycatch in the annual groundfish trawl surveys conducted by DFO. The results of this preliminary work were summarized in MacIsaac et al. (2001). They confirmed that deep-water corals continue to be an important component of the benthic seascape off Nova Scotia. A total of 15 taxa were observed alive in their natural habitat. Corals were observed in all regions surveyed and the results were in general agreement with the observations summarized by Breeze et al. (1997), although the ranges of some species were extended.

In the summer of 2000, over 100 scientists from around the world gathered in Halifax, N.S. for the First International Symposium of Deep-Sea Corals which was organized under the lead of the Ecology Action Centre (based in Halifax). New data on deep-water corals from around the world were presented and strategies for coral conservation were discussed. This event attracted extensive media coverage. Representatives of the fishing and hydrocarbon industries were in attendance. The proceedings were published as a special book (Willison et al. 2001). In addition, some papers were published separately in a special issue of Hydrobiologia (Watling and Risk 2002).

It was recognized at the symposium that, because of its mandate, expertise, and facilities, DFO must continue to play a leading role in collecting more information on deep-water corals in Canada. It was recommended that DFO apply to the Environmental Studies Research Funds (ESRF) for funding in support of an expanded deep-water coral project based at the Bedford Institute of Oceanography (BIO), in particular to hire new scientists to work full-time on corals. The ESRF is an oil and gas industry-funded program, administered by the National Energy Board, that supports environmental and social studies pertaining to exploration, development and production activities on Canadian frontier lands. Accordingly, a proposal for a two-year program (2001-2002) was prepared and submitted to ESRF immediately after the symposium. This was funded shortly thereafter. Dr. Pål Mortensen, who had just finished his PhD thesis studying deep-water corals in Norway, was recruited to work on the project as a Visiting Fellow through the National Scientific and Engineering Research Council (NSERC). In addition, Dr. Lene Buhl-Mortensen, a specialist on deep-water benthic invertebrates, also from Norway, was hired through the Marine Invertebrate Diversity Initiative (MIDI). Funding was also provided to Susan Gass while she conducted her master’s degree in environmental studies at Dalhousie University. Later on, ESRF provided funding for a third year of the project (2003).

The ESRF-funded deep-water coral project, officially titled “Deep Water Benthic Community Study”, had four principle objectives:

- Increase the understanding of the distribution and abundance of deep-water corals in Atlantic Canada
- Describe the structure of coral aggregations, their habitat characteristics and controlling environmental factors

- Describe patterns of diversity and distribution of associated fauna and the role of corals in their life histories
- Study coral biology (morphology, feeding, growth, behaviour, genetics, etc.)

During 2001-2003, a large amount of new information on deep-water corals in Atlantic Canada was collected under this ESRF-funded project. Data sources included DFO groundfish trawl surveys, the Fisheries Observer Program, interviews with fishers, and dedicated cruises to particular areas of interest using DFO research vessels and equipment. In addition, some laboratory work was done using live corals. This project was conducted in collaboration with university scientists, and its design was influenced by input from the hydrocarbon and fishing industries.

The purpose of this report is to document the activities and summarize the major results of this three-year project. The prime audience is government managers and industry clients. Full details of the methods, results and interpretation are provided in a series of scientific publications which are in various stages of development. These are referenced throughout this report and listed in Appendix 2.

SAMPLING METHODS

Groundfish Surveys

DFO conducts annual trawl surveys in all regions of Atlantic Canada to determine the distribution and abundance of various groundfish and shellfish species. Corals can be incidentally captured as bycatch. Formal requests were made to the different DFO regions that all corals collected be saved. Survey technicians were instructed to place corals in a plastic bag, label with cruise and set numbers, and freeze the bag. After each cruise, samples were sent to BIO for storage and analysis. See Gass (2002) for more details. The CCGS *Needler* (Maritimes Region) used a 30 min tow at 3.5 knots with a Western IIA otter trawl, the CCGS *Teleost* (Newfoundland Region) used a 15 min tow at 3 knots with a Campelen 1800 shrimp trawl, while the MV *Paamiut* (Central and Arctic Region) used a 30 min tow at 3 knots with an Alfredo III otter trawl equipped with rockhopper ground gear. The depth range of coral samples collected in the groundfish surveys was 154-1400 m. These surveys provided coral specimens at minimal cost. However, there was no control over the choice of sampling location (stratified random sampling for set location), but geographic reference to the samples was provided as positions and depths of start and end of the sets. The specimens collected on these surveys were used for determining the distribution and morphology of coral species and identifying the associated fauna that survive washout during fishing and retrieval.

Fisheries Observer Program

Fisheries observers, hired by industry, record bycatch data on commercial fishing vessels in Canadian waters. Coverage is 100% on foreign vessels and generally 5-10% for

Canadian vessels. It was formally requested that corals be added to the list of species recorded by the observer, and code numbers were assigned. To assist in the identification of corals, an identification guide with colour photos and short descriptions was prepared for the eight species most commonly caught in fishing gear. This identification guide was later revised and expanded to 14 species in 2003 (see Appendix 1). Observers were requested to record in their log sheets the coral species caught. At the end of each trip, these data were entered into the central bycatch data base maintained by DFO. These data were subsequently recovered along with associated data such as position, depth and gear type. The depth range of coral samples collected by observers ranged from 166 to 720 m and was limited by where commercial fishing took place. See Gass (2002) for more details. Like the groundfish surveys, this program provided coral data at minimal cost. The quality of sampling data was similar that provided from the groundfish surveys, with similar geographic information. However, in most cases, specimens were not provided. This program contributed information on coral distribution.

Interviews with Fishers

Interviews with fishers had previously been shown to be valuable in indicating the distribution of corals off Nova Scotia (Breeze et al. 1997). As part of her master's thesis research, Susan Gass interviewed 36 fishers in Cape Breton and Newfoundland. Full details on the methodology are given in Gass (2002). Even though this method is not entirely reliable when it comes to species identity and abundance, it provides unique insight into historic fishing practices and provides an important background for selecting specific areas for video surveys.

Campod

The principal imaging gear used in this project was Campod, an instrumented tripod equipped with video and still cameras that was designed and built at BIO (Gordon et al. 2000). It was deployed from the CCGS *Hudson* while slowly drifting and collected high-resolution imagery of the seabed habitat and organisms, including corals. A Trackpoint II transponder was attached to provide accurate positioning of the imagery on the seabed. Video imagery and navigation data were recorded on DVCAM digital tape for later analysis. After each cruise, photographs (35 mm slides) were developed, digitized and copied to CD for processing.

Campod can be used over any kind of seabed (e.g. mud, sand, pebble, cobble, boulder, bedrock, etc.) regardless of relief, including steep walls of submarine canyons. Except for the small footprint when it lands, Campod does not disturb the seabed or associated organisms. The imagery can be used to assess the condition of benthic communities, including disturbance by fishing gear. Operating depth was limited by cable length to about 500 m. Survey transect length generally ranged from a few hundred meters to over a kilometer. On most deployments, the ship was allowed to drift with wind and current to cover as much seabed as possible. With Campod, it was possible to target sampling sites of greatest interest. General areas likely to have corals were selected by consulting

Breeze et al. (1997), general bathymetry, benthic ecologists throughout Atlantic Canada, and environmental consultants who have conducted baseline benthic surveys for the oil and gas industry. Specific sampling sites were selected using sidescan sonar and multibeam bathymetry data when available (i.e. Northeast Channel, Scotian Slope and the Gully).

Within the period of this project (2001-2003), Campod was used to collect imagery of deep-water corals on three cruises of CCGS *Hudson*: HUD2001-055 to the Gully, Scotian Slope and Northeast Channel; HUD2002-054 to the Stone Fence, Laurentian Channel and southern edge of the Grand Banks; and HUD2003-059 to the Stone Fence. In addition, Campod imagery collected earlier by the CCGS *Parizeau* on Cruise 97-053 to the Gully, by HUD1999-012 to the Gully and Stone Fence, and HUD2000-020 to the Gully and Northeast Channel was also processed. See Mortensen et al. (2005), Mortensen and Buhl-Mortensen (2004) and Mortensen and Buhl-Mortensen (2005a) for more details on conducting the Campod surveys.

Videograb

Samples of corals were collected with the Videograb, a hydraulically-actuated bucket grab equipped with video cameras designed and built at BIO (Gordon et al. 2000). The operator watched for corals ahead in the oblique video camera, landed the grab over a selected colony when it came into view in the downward looking video camera, and closed the grab. This operation required a skilled operator and careful coordination between lab and deck personnel. Video imagery and navigation data were recorded on DVCAM digital tape for later analysis. As with Campod, operating depth was limited by cable length to about 500 m.

Sampling sites were selected using the results of the Campod video surveys. Sites with the greatest diversity and abundance of corals were generally selected. Live specimens were stored in refrigerated water during transit back to BIO where they were transferred to tanks in the Fish Laboratory. These corals were used for studying behaviour and respiration, and to provide close-up photo documentation of living corals. Samples were also taken for studying associated fauna.

Live corals were collected on three cruises of the CCGS *Hudson*: HUD2000-020 in the Northeast Channel, HUD2001-055 in the Gully and Northeast Channel, and HUD2002-054 in the Gully.

ROPOS

In 2001, imagery and samples of coral were collected on a cruise with the CCGS *Martha L. Black* equipped with ROPOS, an electro-hydraulic Remotely Operated Vehicle (ROV) designed and built by International Submarine Engineering and operated by the Canadian Scientific Submersible Facility (CSSF) located in Sidney, BC. ROPOS was designed for scientific purposes and is equipped with video cameras, sampling equipment and parallel laser beams (10 cm spacing) for sizing objects.

Due to limitations with the ship's crane, the deep water system could not be used so unfortunately, as with Campod, the operating depth for this cruise was limited to 500 m. Deployments were made in Emerald Basin, the Northeast Channel, Verrill Canyon and Dawson Canyon. Mobile fauna were collected from gorgonians in the Northeast Channel using a suction sampler mounted on ROPOS. See Mortensen et al. (2005) and Mortensen and Buhl-Mortensen (2004) for more details on methods for recording and analyses of video transects, and Buhl-Mortensen and Mortensen (2005) for the methods of using the suction sampler.

SAMPLE PROCESSING AND LABORATORY EXPERIMENTATION

Video Analysis of Coral Habitats

Video records were divided into sequences (usually 30 seconds or a distance on the order of 5-25 m) in order to capture habitat differences within a video transect. Position and depth were recorded for the start and end of each sequence. Within these sequences, corals and other organisms were identified and counted and the percent cover of substrate types (i.e. sand, pebble, cobble and boulder) was estimated using the Wentworth scale. Corals were classified as being intact, broken, tilted or dead. Some of the broken, tilted and dead corals could have been the result of natural mortality but other evidence suggests substantial damage from fishing gear in some locations. Colonies with different associated species were counted and the percent coverage on the coral was estimated when the video camera came close enough. Abundance of coral colonies was estimated by dividing the number of colonies within a video sequence by the estimated area of the sequence. An index of roughness was estimated for each video transect as the three-dimensional length of the bottom profile divided by the two-dimensional length (horizontal distance). In total, 84 hours of video footage from 195 transects totalling 118 km were analysed. Full details are given in Mortensen et al. (2005), Mortensen and Buhl-Mortensen (2004) and Mortensen and Buhl-Mortensen (2005a).

Coral Morphology

Morphological information was obtained from samples of *Primnoa resedaeformis* and *Paragorgia arborea* that were collected by groundfish trawl surveys, ROPOS and the Videograb at numerous sites throughout Atlantic Canada ranging from the Northeast Channel to the Davis Strait (Mortensen and Buhl-Mortensen in 2005b). After thawing, individual colonies or fragments were weighed and maximum length, width and base diameter measured. Colonies were photographed from two sides and end branches longer than 3 cm counted. Some broken colonies could be "reconstructed" and the total length and width measured. The proportion of live and dead branches of the colonies was estimated, as was the number of polyps. Morphological information was also obtained from video imagery collected by Campod and ROPOS in the Northeast Channel.

Age

Age was estimated for 38 colonies or fragments of *Primnoa resedaeformis* by counting the dark rings visible in a cross section of the colony base under a binocular microscope (Mortensen and Buhl-Mortensen 2005b). The results were found comparable to counts of growth rings in thin sections embedded in epoxy resin. Attempts to document growth lines representing annual growth cycles did not prove successful for *Paragorgia arborea*. However, growth estimates of *P. arborea* in a Norwegian fjord were made by comparing photographs, obtained from a Norwegian colleague, of the same colony taken 17 months apart by a diver.

Associated Fauna

Samples of associated fauna were collected by groundfish trawl surveys, commercial fisheries, ROPOS and Videograb from five areas in Atlantic Canada ranging from the Northeast Channel to the Davis Strait (Buhl-Mortensen and Mortensen 2005). ROPOS samples were collected using a suction sampler and a remotely operated claw. Samples of corals were frozen in plastic bags immediately after collection, while filtered suction samples were preserved in 4% formaldehyde. In total, 13 samples of *Paragorgia arborea* and 12 samples of *Primnoa resedaeformis* were examined. Before processing in the laboratory, corals were thawed in seawater. Large organisms adhering to corals were removed and placed in 4% formaldehyde. The seawater used for thawing was filtered through a 250 µm sieve and the retained organisms were transferred to 70% alcohol. Corals were weighed and colony length, width and base diameter were measured. All organisms were identified to the lowest possible taxonomic level and counted. Specialists were consulted for the identification of some crustaceans, polychaetes, molluscs and hydroids.

Behaviour

Live corals were held under four different conditions in the Fish Laboratory at BIO.

- Corals were kept in four temperature controlled (about 6 °C) tanks (500 L) with running, unfiltered seawater. This water is drawn from a depth of 5 m in Bedford Basin. Soft corals, stony corals, and horny corals were kept in separate tanks and one tank contained a mixture of the different groups.
- The horny corals *Paragorgia arborea* and *Keratoisis ornata* were held in a large round tank (2000 L) with continuous rotating flow and no cooling of the water.
- For special detailed observations of the soft coral *Duva florida*, an aquarium (100 L) was used supplied with water from a cooled (about 6 °C) reservoir tank.
- Various species were also kept for shorter or longer time in a closed system consisting of two aquaria (about 100 L), a cooling unit (about 6 °C) and a reservoir (1000 L). This system was equipped with a protein skimmer and a mechanical particle filter.

Corals were supplied with unfiltered seawater and therefore able to feed on particles and micro-organisms. However, zooplankton (collected by net in Bedford Basin) and frozen krill were added to all tanks as a supplemental food source at irregular intervals. The temperature and salinity were monitored. The condition of the corals was recorded as the proportion of expanded polyps for horny and soft corals, and additionally the expansion state (contracted, half expanded, fully expanded or hanging) for soft corals. Another expansion scale was used for the polyps of the cup corals (fully retracted, almost fully retracted, almost fully expanded, fully expanded, and swollen). The expansion scales represent an easy and quick way of recording the coral behaviour. Measuring the excact length of polyps and tentacles would give a better resolution, but also much more time consuming. The condition of corals was recorded at irregular intervals (several times per day to twice a week) for each individual coral, in some cases for more than a year. To capture more rapid changes in behaviour, four specimens of cup corals (*Flabellum macandrewi*) were monitored with a time-lapse video camera for periods of up to 48 hours.

DISTRIBUTION AND ABUNDANCE OF DEEP-WATER CORALS IN ATLANTIC CANADA

DFO Groundfish Trawl Surveys, Fisheries Observer Reports and Interviews with Fishers

These results are mainly provided by the work carried out by Susan Gass during her master's study. Corals were collected on four groundfish trawl surveys on the Scotian Shelf, five off Newfoundland and Labrador, and two in the Davis Strait over the period 1999-2001. In total, 57 specimens were collected representing at least seven species (Gass 2002, Gass and Willison 2005). (Table 1)

Table 1. Coral taxa collected in DFO groundfish trawl surveys in Atlantic Canada (1999-2001). Each record indicates a trawl set that brought up a taxa. After Gass (2002).

Taxon	No. of Records
Acanella arbuscula	10
Acanthogorgia armata	7
Flabellum spp.	6
Paragorgia arborea	6
Paramuricea spp.	6
Primnoa resedeaformis	4
Keratoisis ornata	2

As part of the Fisheries Observer Program, over a two year period (2000-2001), observers recorded 170 instances of corals being collected in commercial fishing gear. Six species were collected by four gear types (otter trawls, shrimp trawls, bottom longlines, and bottom gillnets) with longlines accounting for the greatest number of captures (Table 2) (Gass 2002).

Table 2. Coral taxa and their frequency of capture by different gear types as recorded in the Fisheries Observer Program in Atlantic Canada (2000-2001). After Gass (2002).

Taxon	No. of Records	Estimated Weight (kg)	Otter Trawl	Longline	Shrimp Trawl	Gillnet
Primnoa resedaeformis	130	330	7	64	34	25
Paragogria arborea	35	134	9	10	15	1
Paramuricea spp.	2	2	0	2	0	0
Lophelia pertusa	1	2	1	0	0	0
Flabellum spp.	1	1	1	0	0	0
Acanella arbuscula	1	1	0	1	0	0

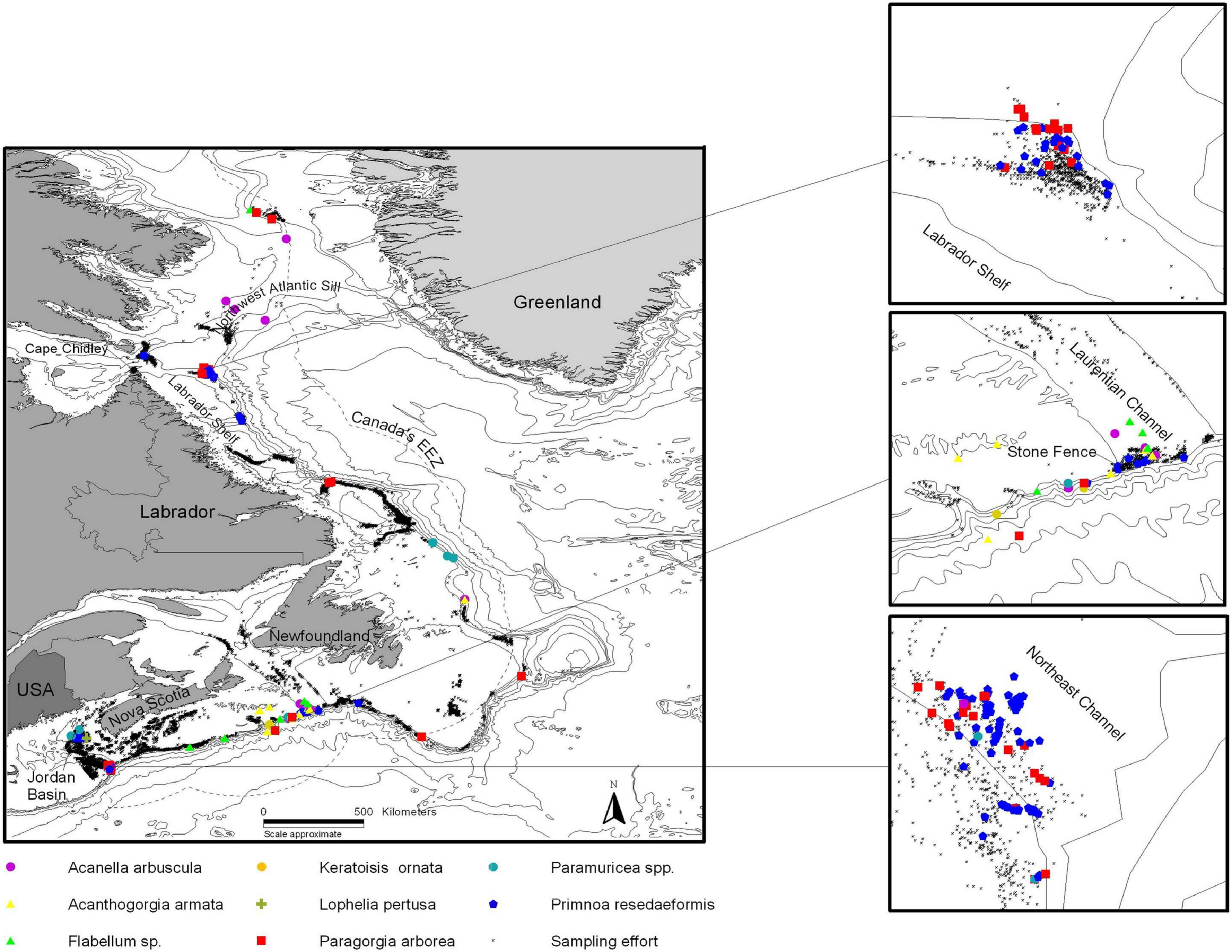

Figure 2. The distribution of deep-water corals (eight taxa) in Atlantic Canada based on bycatch in DFO groundfish trawl surveys (1999-2001) and fishery observer reports (2000-2001). Black Xs indicate sets that did not recover corals. From Gass (2002).

The distribution of corals from both sources is plotted in Fig. 2. The small black "x"s represent trawl sets where corals were not recorded (absence data were not available for three of the five Newfoundland surveys). The records indicate corals ranging all the way from the Jordan Basin in the Gulf of Maine north to the Davis Strait, generally along the edge of the continental shelf. Trawl survey data indicate that species diversity was greatest on the eastern Scotian Shelf between the Gully and Laurentian Channel. The observer records indicate abundant corals in the Northeast Channel (5-10% observer coverage) and east of Cape Chidley (100% observer coverage). Depth distribution of the eight coral taxa observed is summarized in Table 3.

Table 3. Depth range of corals based on data from DFO groundfish trawl surveys and the Fisheries Observer Program. After Gass (2002).

Taxon	No. of Records	Average Depth (m)	Minimum Depth (m)	Maximum Depth (m)
Primnoa resedaeformis	134	319	166	467
Paragorgia arborea	41	361	249	720
Acanella arbuscula	11	622	281	1400
Paramuricea spp.	8	598	154	1159
Acanthogorgia armata	7	551	164	1400
Flabellum spp.	7	428	278	516
Keratoisis ornata	2	416	393	439
Lophelia pertusa	1	166	-	-

Records range from about 150 m down to 1400 m. While the observer data indicate that bottom longlines caught corals most frequently, otter and shrimp trawls captured on average more biomass (Table 4).

Table 4. Average coral biomass captured by gear type as determined from Fisheries Observer reports. After Gass (2002).

Gear	No. of Records	Estimated Weight (kg)	Average Weight/Record (kg)
Bottom longlines	77	142	1.84
Shrimp trawl	49	200	4.08
Bottom gillnets	26	47	1.81
Otter trawl	18	81	4.5

Of the 36 fishers interviewed in eastern Nova Scotia and Newfoundland, 26 had encountered deep-water corals (Gass 2002, Gass and Willison 2005). These were caught while fishing for redfish, grey sole, pollock, halibut, turbot and cod using otter trawls, gillnets and longlines. Eight different taxa were identified (Table 5) and their distributions are shown in Fig. 3.

Table 5. Coral taxa identified by fishers in Atlantic Canada. After Gass (2002).

Taxon	No. of Fishers
Antipatharian	1
Flabellum spp.	2
Keratoisis ornata	3
Acanella arbuscula	4
Lophelia pertusa	5
Paramuricea spp.	6
Trees	7
Primnoa resedeaformis	10
Paragorgia arborea	15

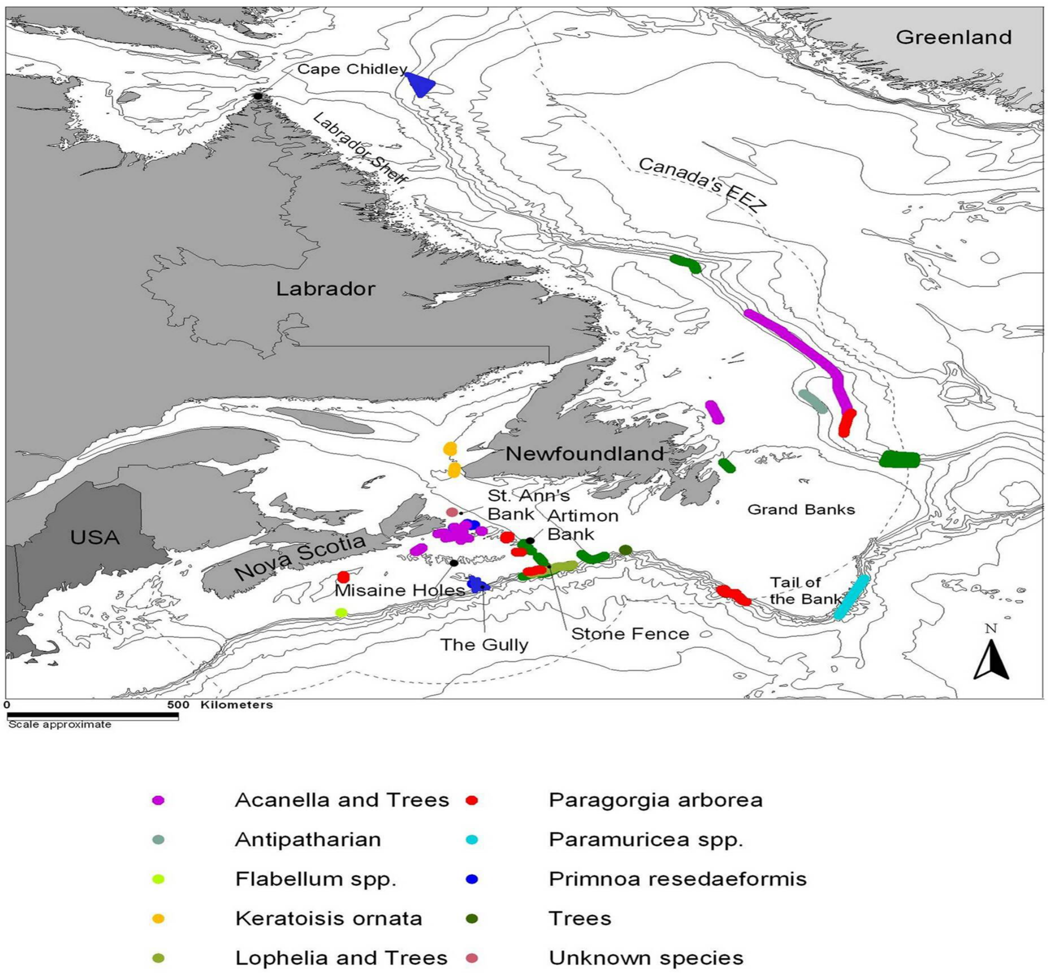

Figure 3. The distribution of deep-water corals (eight taxa) in Atlantic Canada based on the local ecological knowledge of 36 fishers interviewed in Cape Breton and Newfoundland. From Gass (2002).

With the exception of *Acanthogorgia armata,* these are the same taxa reported from the groundfish surveys and observer program (Table 3). Fishers in Nova Scotia identified the Gully and Stone Fence as regions with the most abundant corals. In general, reports of corals in Newfoundland and Labrador waters are more recent since fishing effort has only moved into deeper water since the cod moratorium was introduced in 1992. As off Nova Scotia, the prime area for corals appears to be along the edge of the continental shelf, but there are also reports of corals more inshore around the Funk Islands and off Cape Spear. One fisher produced a sample of coral which turned out to be the first identified antipatharian black coral in Atlantic Canada (*Bathypathes arctica*). Fishers reported that fishing was usually good near corals, that fishing gear was frequently tangled in corals, that large specimens were frequently collected, and that the abundance of coral off Nova Scotia appeared to be decreasing in recent years.

The DFO groundfish trawl surveys, the fisheries observer reports and the fishers' local ecological knowledge were each successful in providing valuable data on the distribution of deep-water corals in Atlantic Canada. These data are in general agreement with the results of Breeze et al. (1997) where they overlap off Nova Scotia, but they also provide new information on the occurrence of deep-water corals off Newfoundland and Labrador as well as further north in the Davis Strait. Of particular note are reports of the reef-building stony coral *Lophelia pertusa,* one by an observer in the Jordan Basin and four by fishers in the Gully and near the Stone Fence. A fifth fisher reported encountering *L. pertusa* but could not recall specifically where he had caught it.

During this study, a record of dead *Lophelia pertusa* was found for Misaine Bank, immediately north of Banquereau. This sample is deposited at the Nova Scotian Museum of Natural History. A fishing captain reported that, in his experience, the greatest abundance of corals on the slopes of outer fishing banks occurred on the eastern slope of Banquereau at 44 28' N in the area known as Stone Fence (Collins 1884). Seldom were all trawl lines set recovered.

Video Imagery Collected by Campod and ROPOS

These results are provided by quantitative analyses of video collected along 195 transects which was carried out by Pål B. Mortensen and Lene Buhl-Mortensen. Results are summarized by geographic region and will also be presented in a paper recently submitted (see Appendix 2).

Northeast Channel

In 2000 and 2001, video records were collected along 52 transects in the Northeast Channel using either Campod (45 transects) or ROPOS (7 transects) (Fig. 4). Deployments were made over a depth range of 183-498 m. Transects varied in length between 301 and 1683 m with a total length of 34 km. As described in detail by Mortensen and Buhl-Mortensen (2004) and Mortensen et al. (2005), *Primnoa resedaeformis* was observed along 35 of the transects, while *Paragorgia arborea* was present along 21 transects (Table 6).

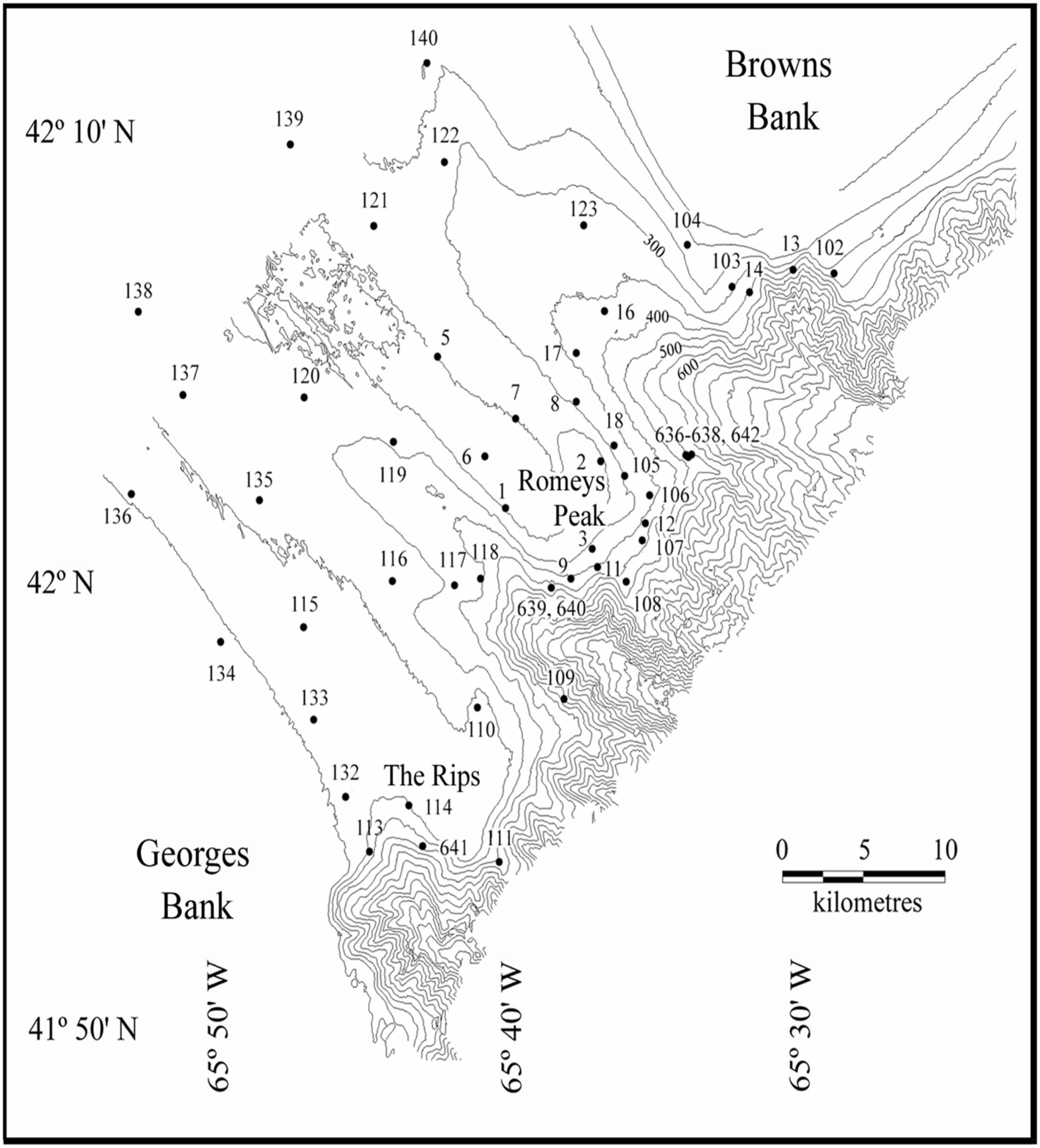

Figure 4. Bathymetry and location of Campod and ROPOS video transect in the Northeast Channel. From Mortensen and Buhl-Mortensen (2004).

Table 6. Summary of video observations in the Northeast Channel (Fig. 4). Taxon, number of specimens observed, the number of transects a taxon was observed on, average abundance (colonies per 100 m^2) on transects where observed, and depth range (m) of deep-water corals in the Northeast Channel. Total number of transects was 52. Total length of transects was 34 km. From Mortensen et al. (2005) and Mortensen and Buhl-Mortensen (2004). Maximum operating depth of the video equipment was about 500 m.

Order	Taxon	Specimens	Transects	Abundance	Depth
Gorgonacea	*Acanthogorgia armata*	212	4	0.5	231-364
	Paragorgia arborea	322	21	0.6	235-498
	Primnoa resedaeformis	2663	35	4.8	196-498

Acanthogorgia armata was observed along just four of the transects. *P. resedaeformis* was the most abundant species. Average abundance for *P. arborea* and *P. resedaeformis* on transects with corals was 0.6 and 4.8 colonies per 100 m^2, respectively (Table 6). The highest local abundances for *P. arborea* and *P. resedaeformis* were 49 and 104 colonies per 100 m^2, respectively. The average abundance for *A. armata* was 0.5 colonies per 100 m^2. The most frequent occurrences of *P. resedaeformis* and *P. arborea* were on the northern side of Romeys Peak and in the valley between The Rips and Romeys Peak (Fig. 5).

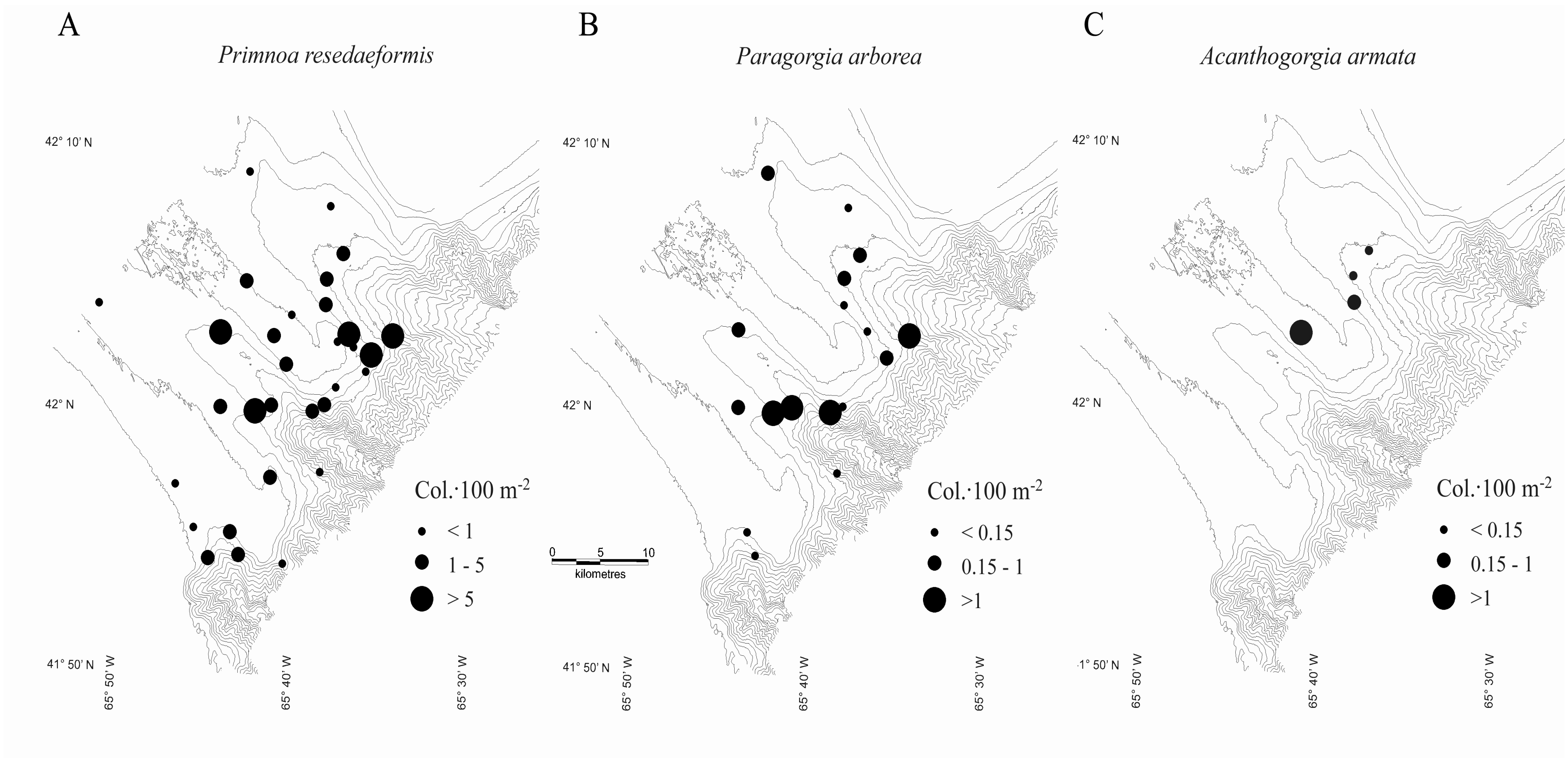

Figure 5. Distribution and abundance (colonies per 100 m^2) of deep-water corals (three taxa) in the Northeast Channel. From Mortensen and Buhl-Mortensen (2004).

The shallowest observations of *P. resedaeformis* and *P. arborea* occurred at 196 m and 235 m, respectively. The highest densities were observed between 410 and 490 m. The range of both species extends well below 500 m, the operational depth limit for Campod and ROPOS. *A. armata* was observed between 231 and 364 m.

The overall distribution of corals in the Channel was related to the general current pattern with an inflow on the northern side and an outflow in the centre and on the southern side. The corals were almost totally absent on the northern side along the flanks of Browns Bank whereas they were most abundant in the outward flowing water which is presumably rich in food particles.

Scotian Slope

In 2001, video transects were made using Campod at 24 locations along the Scotian Slope between the Northeast Channel and Verrill Canyon (Fig. 1). Corals were observed at 14 of these locations in the depth range of 346-500 m. Four coral species (*Flabellum alabastrum, F. macandrewi, F.* cf. *angulare,* and *Duva florida*) were observed. *Flabellum* spp. and *F. alabastrum* were the most common occurring along 54 and 46 % of the investigated transects respectively. The cup coral *Flabellum* spp. was the dominant coral taxon with an average abundance of 29.2 individuals per 100 m^2 (Table 7). Some seapens were also observed but no gorgonians. Four ROPOS video transects in Verrill and Dawson Canyons indicated the presence of soft corals and cup corals but no gorgonians.

Table 7. Summary of video observations along the Nova Scotian Slope (Fig. 1). Taxon, number of specimens observed, the number of transects a taxon was observed on, average abundance (colonies per 100 m^2) on transects where observed, and depth range (m) of deep-water corals. Total number of transects was 24. Total length of transects was 16 km. Maximum operating depth of the video equipment was about 500 m.

Order	Taxon	Specimens	Transects	Abundance	Depth
Alcyonacea	*Duva florida*	3	2	0.01	367-427
	Nephtheidae sp.1 (blue)	1	1	<0.01	427
Scleractinia	*Flabellum alabastrum*	292	11	1.2	346-500
	Flabellum macandrewi	49	4	0.2	420-500
	Flabellum sp.1 (red)	303	7	1.3	346-492
	Flabellum spp.	7040	13	29.2	346-492

The Gully

In 1997, 1999, 2000 and 2001, Campod video transects were run at 49 sites in the Gully ranging in depth from 110 to 544 m (Fig. 6). In 2001 twenty-two sites were selected in areas of rugged seabed topography most likely to support corals. The rest of the sites were selected to fill in areas poorly represented in order to describe the geographical distribution and the upper depth limit of the corals. Transects varied between 19 and 1327 m in length covering a total distance of 17 km. Full details are given in Mortensen and Buhl-Mortensen (2005a).

Except for shallow water near the head, corals were common throughout the Gully. A total of 16 taxa of corals was identified; 5 Alcyonacea, 6 Gorgonacea and 5 Scleractinia (Table 8).

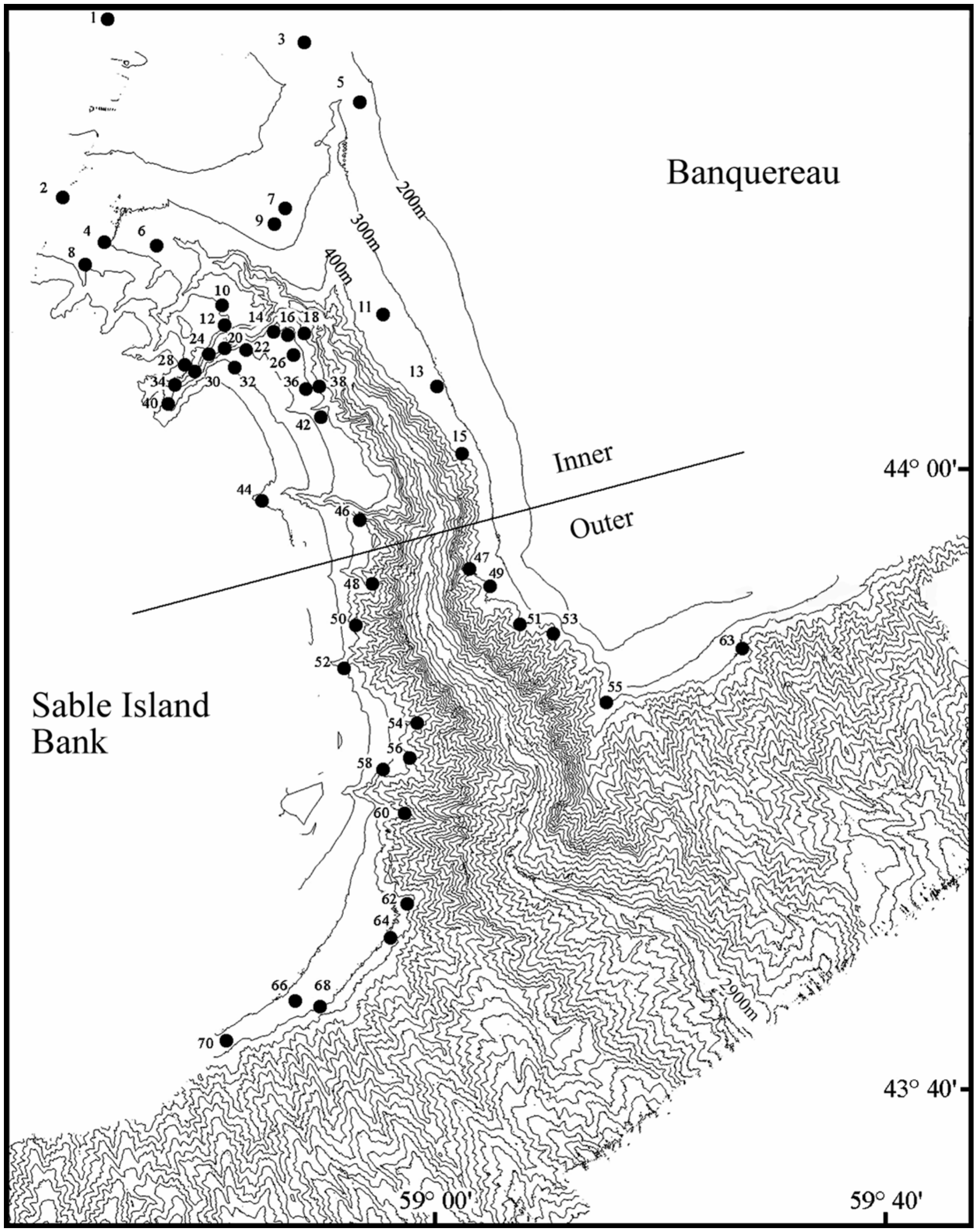

Figure 6. Bathymetry and location of Campod video transects in the Gully. From Mortensen and Buhl-Mortensen (2005a). The straight line denotes the separation between the inner and outer Gully.

Table 8. Summary of video observations in the Gully (Fig. 6). Taxon, number of specimens observed, the number of transects a taxon was observed on, average abundance (colonies per 100 m^2) on transects where observed, and depth range (m) of deep-water corals. Total number of transects was 49. Total length of transects was 17 km. From Mortensen and Buhl-Mortensen (2005a). Maximum operating depth of the video equipment was about 500 m.

Order	Taxon	Specimens	Transects	Abundance	Depth
Alcyonacea	*Anthomastus grandiflorus*	17	6	0.2	399-523
	Duva florida	1498	18	5.2	172-537
	Nephtheidae sp.1 (blue)	160	9	2.3	270-446
	Nephtheidae sp.2 (white)	186	14	1.8	287-539
	Nephtheidae Indet.	403	13	2.1	237-538
Gorgonacea	*Acanella arbuscula*	74	5	3.4	404-540
	Acanthogorgia armata	32	4	0.7	346-493
	Keratoisis ornata	63	8	0.9	396-509
	Paragorgia arborea	28	7	0.3	341-495
	Primnoa resedaeformis	108	4	2.0	388-516
	Radicipes gracilis	40	7	0.7	404-535
Scleractinia	*Flabellum alabastrum*	116	10	0.9	341-541
	Flabellum macandrewi	3	1	-	439
	Flabellum spp.	3396	12	12.1	404-439
	Flabellum sp.1 (red)	1124	3	94.1	337-541
	Lophelia pertusa	1	1	-	450

Up to 11 species were found on a single transect. The corals showed distribution patterns with distance along the axis of the canyon, depth and type of seabed. Most corals occurred deeper than 350 m. The spatial distribution of dominant species is shown in Fig. 7. *Primnoa resedaeformis* and *Paragorgia arborea* were found in both the inner and outer Gully (as defined in Fig. 6). *Acanella arbuscula* and *Acanthogorgia armata* were found only near the mouth of the Gully. Gorgonians were only observed deeper than 340 m. Alcyonaceans were found throughout the Gully while *Flabellum* species were found mainly in the outer Gully. A small fragment of *Lophelia pertusa* was spotted in the inner Gully but it was not possible to determine if it was alive. The shallowest observed depth for alcyonarians was 172 m and about 340 m for gorgonians and scleractinians (Table 8). Again, nothing can be said about the deepest depths to which most coral species extend because of the restrictions set by the cable length of Campod (about 500 m). However, photographs taken in the outer Gully using a Benthos deep-sea camera indicate that *Keratoisis ornata* extends to at least 767 m, *Radicipes* spp. to at least 1287 m and *Anthomastus grandiflorus* to at least 1326 m (Kostylev 2000).

Small corals were more abundant than larger ones. The most abundant coral was the solitary cup coral *Flabellum* spp. which had an average abundance along transects where present of 106 per 100 m^2 (Table 8), higher than the average observed along the Scotian Slope (Table 7). The most abundant colonial coral was the soft coral *Duva florida* with an average abundance of 5.2 per 100 m^2. The most abundant gorgonian was *Acanella arbuscula* which had an average abundance of 3.4 per 100 m^2. Average abundance for all coral species combined was 13.2 colonies per 100 m^2. The abundance and diversity of corals was higher in the outer part of the Gully than the inner part. The western side of the Gully tended to have a higher abundance and diversity of corals than the eastern side. This is thought to be related to circulation patterns and presumably higher food concentrations in the out-flowing water.

Overall, the abundance of corals in the Gully is lower than reported for the Northeast Channel (Mortensen et al.2005, Mortensen and Buhl-Mortensen 2004) and the Sula Reef off Norway (Mortensen et al. 1995), but is comparable to what is found in canyons off the northeast US (Hecker et al. 1980). However, it must be kept in mind than the seabed deeper than 500 m in the Gully has yet to be surveyed with video.

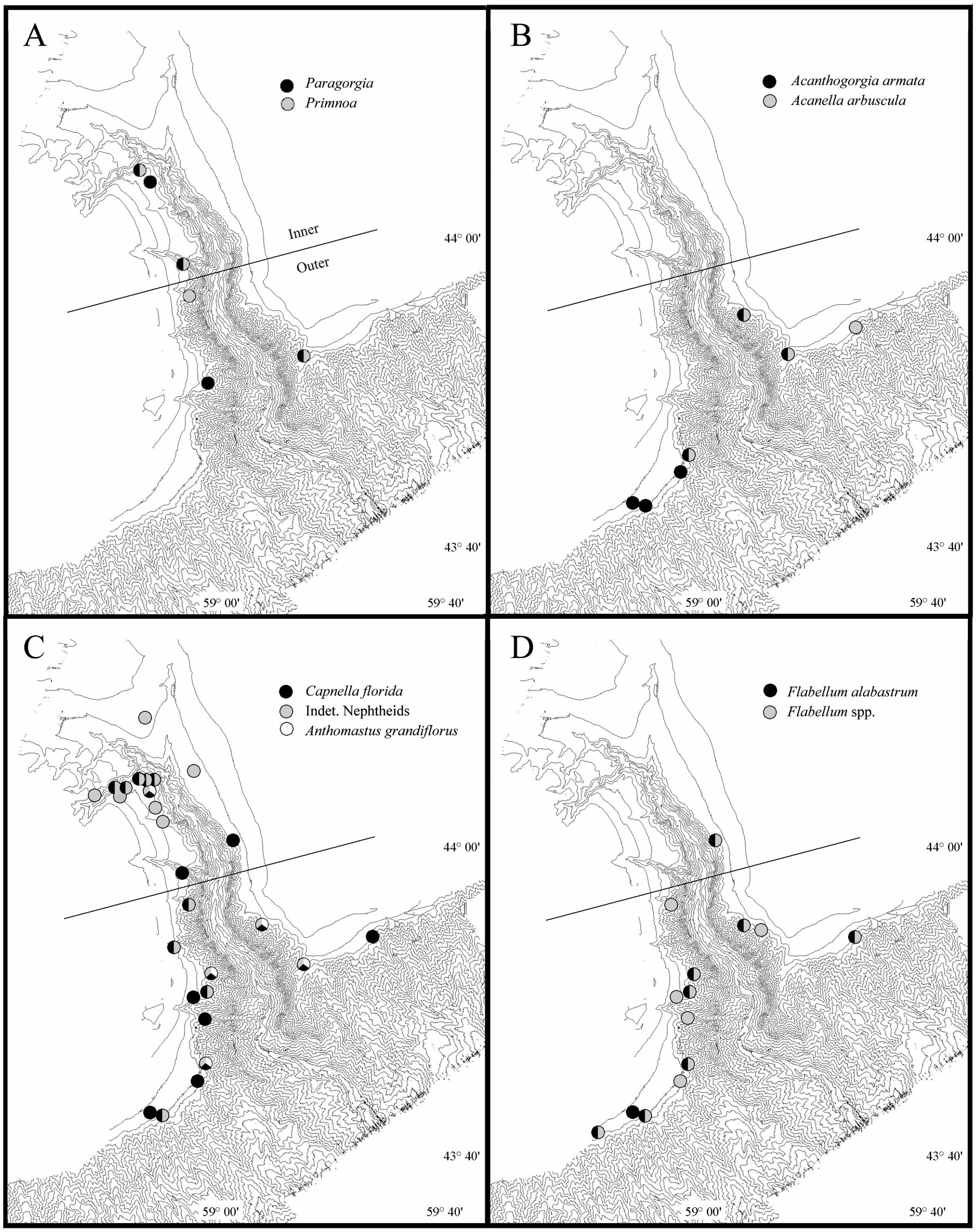

Figure 7. Distribution of deep-water corals (16 taxa) in the Gully. From Mortensen and Buhl-Mortensen (2005a).

Stone Fence

Video observations made in 1999 indicated a high diversity of coral species along the Stone Fence at the mouth of the Laurentian Channel (MacIsaac et al. 2001). The area was revisited in 2002 and Campod video transects were run at 15 locations (Fig. 8). Corals were found along all transects. Of particular note was the observation of a live fragment of *Lophelia pertusa*, about 15 cm in size, which marked the first time that this species was seen alive in its natural habitat in Atlantic Canada. In 2003, a more concentrated Campod survey with 24 video transects was conducted near the area where the live *L. pertusa* was observed in 2002 (Fig. 8). Thirty patches of skeletal rubble were identified. Fourteen of these contained living colonies or fragments while 12 contained dead blocks. A total of 67 live colonies of *L. pertusa* were observed and most were relatively small (< 30 cm in height). Dead *L. pertusa*, both rubble and blocks, was much more abundant than living coral. Most of the living colonies were observed between 300 and 320 m. These observations indicate the presence of a reef complex within an area of approximately 490 by 1300 m (about 0.6 km^2) (Fig. 9). This is the first documented observation of a *L. pertusa* reef complex in Atlantic Canada. Combining data for both years, nine taxa of coral were observed (Table 9). These observations will be presented in more detail in a paper about to be submitted (see Appendix 2). In general, both the abundance and diversity of corals at the Stone Fence observed in the video appear to be less than what was observed in the Gully (Table 8). However, Collins (1884) reported that the Stone Fence had the highest abundance of deep-water corals which indicates that abundance may have decreased over the past century.

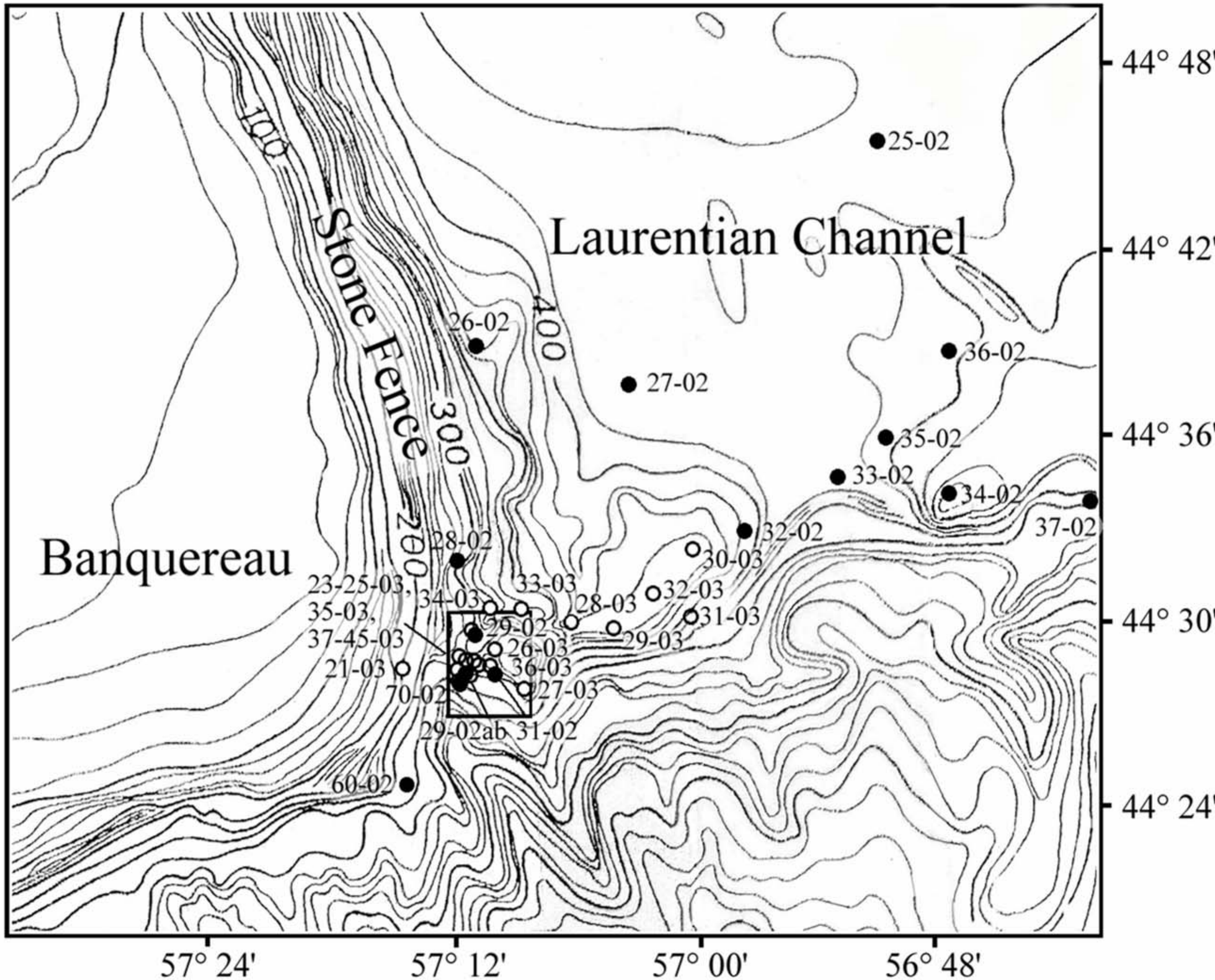

Figure 8. Bathymetry and location of Campod video transects near the Stone Fence at themouth of the Laurentian Channel. The box indicates the approximate location of Fig. 9.

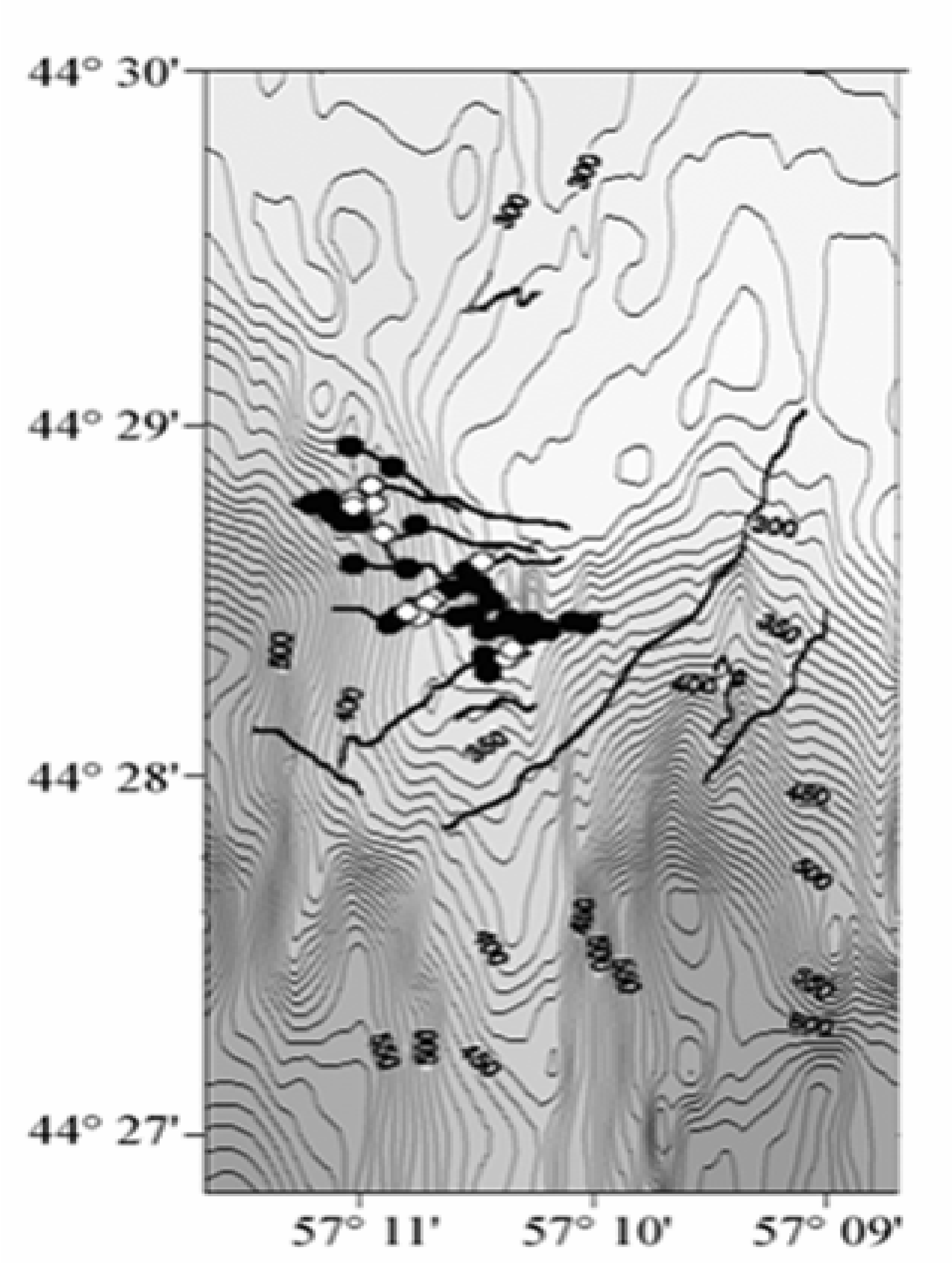

Figure 9. The location of *Lophelia* sightings, both live colonies and dead, near the Stone Fence at the mouth of the Laurentian Channel plotted over the bathymetric data recorded on HUD2003-059. The thick lines indicate the path of Campod transects.

Table 9. Summary of video observations near the Stone Fence at the mouth of the Laurentian Channel (Fig. 8). Taxon, number of specimens observed, the number of transects a taxon was observed on, average abundance (colonies per 100 m^2) on transects where observed, and depth range (m) of deep-water corals. Total number of transects was 40. Total length of transects was 40 km. Maximum operating depth of the video equipment was about 500 m.

Order	Taxon	Specimens	Transects	Abundance	Depth
Alcyonacea	*Anthomastus grandiflorus*	521	22	0.49	260-502
	Duva florida	1449	20	1.38	260-500
	Nephtheidae sp.2 (white)	96	4	0.09	236-404
Gorgonacea	*Acanella arbuscula*	19	6	0.02	246-483
	Acanthogorgia armata	288	24	0.27	260-502
	Keratoisis ornata	44	17	0.04	271-502
	Primnoa resedaeformis	297	17	0.27	260-414
	Paragorgia arborea	115	20	0.10	260-502
Scleractinia	*Lophelia pertusa* (live)	12	8	0.01	260-400

Laurentian Channel

In 2002, Campod video transects were run at 20 sites in the Laurentian Channel (Fig. 1). Corals were found along nine of the transects. Six taxa were identified (Table 10).

Table 10. Summary of video observations in the Laurentian Channel (excluding the Stone Fence region) (Fig. 1). Taxon, number of specimens observed, the number of transects a taxon was observed on, average abundance (colonies per 100 m^2) on transects where observed, and depth range (m) of deep-water corals. Total number of transects was 18. Total length of transects was 7.2 km. Maximum operating depth of the video equipment was about 500 m.

Order	Taxon	Specimens	Transects	Abundance	Depth
Alcyonacea	*Duva florida*	8	1	0.96	340
	Gersemia rubiformis	17	1	0.46	245
Gorgonacea	*Acanthogorgia armata*	60	1	1.90	340
	Radicipes gracilis	1	1	0.09	348
Scleractinia	*Flabellum alabastrum*	34	4	0.67	305-414
	Flabellum spp.	54	7	0.63	305-414

Depth range was 245-414 m. In general, the abundance of corals was low with a maximum for *Acanthogorgia armata* of 1.90 colonies per 100 m^2 at Transect CP08 in the Cabot Strait. This species occurred with the highest abundance on average (1.1 col. per 100m^2), and was observed along 7 % of the transects The most common taxon was *Flabellum* spp. occurring along 7 transects. *Flabellum alabastrum* was observed along four transects whereas all other species occurred only on one or two transects. *Gersemia rubiformis* was observed with 17 colonies, with an average abundance of 0.5 colonies per 100m^2 in La Poile Bay (CP16). Possible dead *L. pertusa* was sighted at Transect CP12 in one of the holes on Misane Bank along the western side of the Channel. Dead *L. pertusa* had previously been reported by fishers to the northwest of this location (material stored at the Nova Scotia Museum of Natural History).

Southern Edge of the Grand Banks

In 2002, Campod video transects were also run at 11 sites in the Haddock and Halibut Channels along the southern edge of the Grand Banks (Fig. 1). Corals were found at seven of the transects. Nine taxa were identified (Table 11). Depth range was 370-518 m. In general, abundance was low with the most abundant taxa being *Duva florida*, *Flabellum alabastrum* and *Flabellum* spp. *Acanthogoria armata* was also relatively common.

Table 11. Summary of video observations in the Haddock and Halibut Channels along the southern edge of the Grand Banks (Fig.1). Taxon, number of specimens observed, the number of transects a taxon was observed on, average abundance (colonies per 10 m^2) on transects where observed, and depth range (m) of deep-water corals. Total number of transects was 11. Total length of transects was 4.2 km. Maximum operating depth of the video equipment was about 500 m.

Order	Taxon	Specimens	Transects	Abundance	Depth
Alcyonacea	*Anthomastus grandiflorus*	2	1	0.13	421
	Duva florida	107	4	1.53	504
	Nephtheidae Indet.	16	4	0.32	409
Gorgonacea	*Acanella arbuscula*	169	2	0.13	409-421
	Acanthogorgia armata	38	6	0.40	370-518
	Keratoisis ornata	1	1	0.07	421
	Radicipes gracilis	15	1	0.86	409
Scleractinia	*Flabellum alabastrum*	177	4	1.91	409-518
	Flabellum spp.	158	5	1.27	370-518

Updated Systematic List

Breeze et al. (1997) prepared a systematic list of corals thought to occur in Atlantic Canada. Several of these species have not yet been confirmed to reside here. An updated systematic list based upon the results of this study is presented in Table 12.

Table 12. Systematic list of deep-water corals off Atlantic Canada documented by this project together with earlier records reviewed by Breeze et al. (1997). The material used by this project included the Atlantic Reference Centre (ARC) collection, Campod video records, samples collected with ROPOS and Videograb, and bycatch records from DFO groundfish surveys and commercial fisheries.

Taxon	**Synonyms**	**ARC Collection**	**Video Records**	**ROV and Videograb**	**Bycatch**	**Breeze et al. (1997)**
Class Octocorallia Order Alcyoncea (Soft Corals) Family Alcyoniidae						
Anthomastus grandiflorus (Verrill 1878)	*Anthomastus purpureus, Sarcophytum purpeum*	X	X	X		X
Family Nephtheidae						
Duva florida (Rathke in Muller 1806)	*Duva mulitiflora, Capnella florida, Duva rosea, Duva spitzbergensis, Eunephthya florida, Eunephthya spitzbergensis, Paraspongodes rosea*	X	X	X		X
Drifa glomerata (Verrill 1869)	*Eunepthya glomerata, Capnella glomerata, Eunepthya rosea, Nephthya flavescens, Nephthya rosea*	X				X
Eunephthya cf.fruticosa (Sars 1860)	*Gersemia fruticosa* (Sars 1860)	X				X
Gersemia rubiformis (Ehrenberg 1834)	*Eunepthya clavata, Gersemia clavata, Gersemia fruticosa, Paraspongodes fruticosa*	X	X			X
Order Gorgonacea (Horny Corals)						
Family Anthothelidae						
Anthothela grandiflora (Sars 1856)	*Briareum grandiflorum, Paragorgia grandiflora,*	X				X
Family Paragorgiidae						
Paragorgia arborea (Linnaeus 1758)	*Alcyonium arboreum*	X	X	X	X	X
Family Acanthogorgiidae						
Acanthogorgia armata		X	X	X	X	X

(Verrill 1878)						
Family Chrysogoroiidae						
Radicipes* cf. *challengeri (Wright 1885)			X			
Radicipes gracilis (Verrill 1884)			X	X		X
Family Clavulariidae						
Trachythela rudis (Verrill 1922)					X	
Family Isidiidae						
Acanella arbuscula (Johnson 1862)		X	X	X	X	X
Keratoisis ornata (Verrill 1878)		X	X	X	X	X
Family Plexauridae						
Paramuricea placomus (Linnaeus 1758)	*Clavularia stormi,* *Muricea placomus,* *Muriceides ramosus,* *Paramuricea elegans*	X			X	X
Paramuricea grandis (Verrill 1883)	Lepidomuricea grandis (Verrill, 1883)	X				X
Family Primnoidae						
Primnoa resedaeformis (Gunnerus 1763)	*Prymnoa lepadifera*	X	X	X	X	X
Family Xeniidae						
Anthelia borealis (Koren and Danielssen 1883)		X				
Class Hexacorallia Order Anthipatharia (Black Corals) Family Antipathidae						
Cf. *Bathypathes* sp.		X			X	
Order Scleractinia (Stoney Corals) Family Caryophylliidae						
Lophelia pertusa (Linnaeus 1758)	*Madrepora pertusa,* *Lophohelia prolifera*	X	X		X	X
Family Flabelliidae						
Flabellum alabastrum (Moseley 1876)	*Flabellum goodei*	X	X	X	X	X
Flabellum angulare (Moseley 1881)	*Flabellum goodei*			X		
Flabellum macandrewi (Gray 1849)			X			
Javinia cailleti (Duchassaing and Michelotti 1864)	*Desmophyllum nobile,* *Desmophyllum eburneum*					X
Tally		**17**	**13**	**10**	**10**	**17**

STRUCTURE OF DEEP-WATER CORAL AGGREGATIONS, THEIR HABITAT CHARACTERISTICS AND CONTROLLING ENVIRONMENTAL FACTORS

Northeast Channel

As reported by Mortensen and Buhl-Mortensen (2004) and Mortensen et al. (2005), the distribution of the three gorgonian species observed (*Primnoa resedaeformis*, *Paragorgia arborea*, and *Acanthogorgia armata*) was patchy and restricted to areas with cobbles and boulders. No corals were observed attached to sand or pebbles. Boulders were commonly observed on most transects but seldom covered more than 50% of the seabed. On average, for all transects, the percent cover of cobble and boulder was 21% and 9%, respectively. Many boulders had no corals attached indicating that suitable substrate is not limiting. Large colonies of *P. arborea* were observed almost exclusively on boulders, whereas smaller colonies were often observed on cobbles as well. *P. resedaeformis* occurred on both cobbles and boulders, while *A. armata* was found only on cobbles. Both *P. resedaeformis* and *P. arborea* were frequently found on the same boulder. There was no sign of competitive exclusion at any spatial scale.

Corals were more common in the outer part of the Channel compared to the inner (Mortensen and Buhl-Mortensen 2004). Transects with the highest abundance of corals were characterized by a depth greater than 400 m, a maximum water temperature less than 9.2 °C, and a relatively high percent coverage of cobble and boulders. High temperatures probably control the upper depth limit of the corals. *Primnoa resedaeformis* seems to tolerate slightly higher temperatures than *Paragorgia arborea* (about 13 °C compared to about 10 °C). Abundance of both species was negatively correlated with average temperature and positively correlated with cobbles. Together, temperature, percent cobble and salinity accounted for 38% of the variance of *P. resedaeformis* compared to 15% for *P. arborea*. Large scale topographic features governing current regimes and the supply of food and larvae also appear to play a controlling role in coral distribution.

No reef structures were observed in either the video footage or the sidescan and multibeam data. If present, large reef structures should have been detected in the multibeam imagery which covered the entire area of the outer Northeast Channel (as deep as 1000 m in places). There have been no confirmed reports of reef-building *Lophelia pertusa* in this area. The dominant corals, the gorgonians *P. resedaeformis* and *P. arborea*, are not reef-building species, but where they occur in dense patches the habitat can be characterized as a “gorgonian forest”.

Scotian Slope

The seabed at the slope transects examined was composed of soft sediments (e.g. silt and sand). The only hard substrate was some very sparse cobble. No boulders were observed. Individuals of the dominant taxon (*Flabellum* spp.) were small and not attached. When observed, the soft coral *Duva florida* was attached to cobble. Probably, lack of hard substrate and topographic relief limit the distribution of corals in this part of the study area.

The Gully

Geological features of the benthic habitat of the Gully has been previously described in detail by Fader and Strang (2002) and Kostylev (2002), based on interpretation of multibeam data for the entire area and the video and photographic imagery at selected transects available up to and including 2000. As described by Mortensen and Buhl-Mortensen (2005a), the Gully has a high diversity of habitats including steep bedrock outcrops, high relief ledges, gravel and soft level bottoms. The percent coverage of different substrate types in the video footage reviewed was 53% mud, 32% sand, 5.2% pebble, 5.1% semi-consolidated mudstone, 3.5% cobble and 0.6% boulder. The area of cobble and boulder was much less than observed in the Northeast Channel (21% and 9%, respectively). Sand was more common in the shallow inner part of the Gully while mud was more common in the deeper, outer part of the Gully. Sudden changes in substrate were often related to changes in slope. Bottom temperature in the Gully ranges between 1.9 and 10.3 C and averaged 5.3 C. Salinity was generally between 34.55 and 34.86 psu.

Corals were found in most parts of the canyon. Their distribution patterns were mainly related to distance along the axis from the canyon head, depth and the type of seabed. The substrate in the shallow, inner Gully consists mainly of muddy sand. The only corals observed were alcyonarians attached to scattered cobbles. The most common organisms in this habitat were cerianthid anemones. In other parts of the Gully above the shelf break, the seabed was muddier and *Flabellum* spp. was abundant. Below the shelf break, the seabed becomes coarser and has patches of gravel that support a great diversity of suspension feeders. Here, the gorgonian *Acanthogorgia armata* and the alcyonarian *Anthomastus gradiflorus* were observed on cobbles and boulders. On transects in small side canyons, a rugged terrain was observed with extensive outcrops of semi-consolidated mudstone. Soft corals were situated on the crests of these structures, also *Paragorgia arborea* and *Primnoa resedaeformis* where mudstone was exposed. Elsewhere, *P. arborea* and *P. resedaeformis* were more commonly found on boulders. The gorgonian *Keratoisis ornata* was often observed on cobbles and boulders in the bottom of small channels. *Flabellum* spp. and *Acanella arbuscula* were generally associated with the finer, more level sediments in the outer part of the Gully. *K. ornata*, *P. resedaeformis* and Nephtheidae indet. were associated with steep slope and exposed mudstone. Except for *A. arbuscula* and *Radicipes* spp., which are anchored in soft sediment, gorgonians were mainly confined to areas with cobble and boulders, and in a few cases semi-consolidated mudstone. On the other hand, the soft corals utilized a wide range of substrates including the semi-consolidated mudstone.

Multivariate analyses by Mortensen and Buhl-Mortensen (2005a) indicated that the distribution of corals in the Gully is controlled in part by distance along the axis, salinity, substrate type and slope. However, much of the variation in coral distribution could not be explained by environmental variables. The highest abundance of corals, found on the western side in the outer part of the canyon, is probably related to circulation patterns with a higher load of particulate matter in the out-flowing water.

No reef structures were observed in either the video footage or the sidescan and multibeam data. If present, large reef structures should have been detected in the multibeam imagery that covered the entire Gully down to depths in excess of 2000 m. The dominant corals, *Flabellum* spp., Nephtheidae indet. and *Acanella arbuscula*, are not reef-building species.   However, there are reports of *Lophelia pertusa* in the Gully so the possibility of some small reef structures still exists.

Stone Fence

The video observations indicated the presence of a *Lophelia pertusa* reef complex of smaller coral mounds within an area of approximately 490 x 1300 m (Fig. 9). Locally, *L. pertusa* rubble, with some infill of finer sediment, covered up to 100 % of the bottom. *L. pertusa* occurred as live or dead fragments in clusters in isolated rubble areas typically extending horizontally 10 to 100 m. These rubble areas probably represent former reefs. The height of these accumulations of coral (both rubble and larger dead fragments) was difficult to measure but was estimated to be about 3 m. The largest living colonies were about 1.5 m wide but the tops have been broken off. Mortensen et al. (2001) found a linear relationship between area and height of individual *L. pertusa* reefs off Norway. Based on that relationship, the height of an undisturbed *L. pertusa* reef can be expected to be about 20 % its diameter. Therefore, the Stone Fence reef could have originally been as high as 20 m. Relatively small colonies of *Paragoria arborea* were observed and many of these were tilted or attached to the sides of boulders. The location of the reef complex on the western side of the mouth of the Laurentian Channel is thought to be due in part to higher food concentrations in outflowing water.   More details are given in a paper about to be submitted (see Appendix 2).

Laurentian Channel

In general, the relatively low abundance of corals in the Laurentian Channel, other then the Stone Fence, probably reflects the low cover of cobble and boulder in this area.

MORPHOLOGY, GROWTH, AND BEHAVIOUR OF DEEP-WATER CORALS

Morphology

As described by Mortensen and Buhl-Mortensen (2005b), maximum height and width were measured for 184 *Paragorgia arborea* colonies and 1561 *Primnoa resedaeformis* colonies.   The height of *P. arborea* colonies ranged from 5 to 180 cm with an average of 57 cm, while the height of *P. resedaeformis* colonies ranged from 5 to 86 cm with an average of 30 cm. There was a significant correlation between height and base diameter for both species. *P. arborea* colonies generally had thicker trunks and branches than *P. resedaeformis*. Most *P. arborea* colonies were more or less circular in outline while *P. resedaeformis* colonies were more oblong with conical branches widening at the top. The height of *P. arborea* colonies was positively correlated to the size of the boulders to which they were attached. The maximum height seems to be approximately twice the diameter of the boulder. It appears that strong currents can roll over boulders with corals colonies exceeding this critical height. Therefore some of the tilted corals observed could be caused by natural processes rather than fishing activities.

Paragorgia arborea was observed to occur in three colour varities: salmon, red and white (Mortensen and Buhl-Mortensen2005b). The red and white varieties each contributed 41% to the population while 18% of the colonies were salmon-coloured. On average, salmon-coloured *P. arborea* colonies were taller then the red and white varieties. As the varieties co-occur, these differences in colour are though to be related to genetics and not environmental factors.

Most *P. arborea* colonies larger than 50 cm were concave-shaped and oriented into the prevailing near-bottom current (Mortensen and Buhl-Mortensen 2005b). Polyp density was higher for *P. resedaeformis* than *P. arborea* but for both species polyp density was greatest on the outer branches. *P. arborea* most commonly occurred on the top of boulders. *P. resedaeformis* did not reflect the main current direction to the same degree as *P. arborea* but commonly occurred on the up-current side of boulders. The different height, morphology and position on boulders of these two gorgonian species suggests they utilize different food sources. *P. resedaeformis* seems to be adapted to a near bottom environment with turbulent currents while *P. arborea* seems more adapted to uni- or bi-directional currents higher off the seabed and develops planar colonies perpendicular to the prevailing current. The orientation of large *P. arborea* colonies provides a picture of near bottom-current patterns integrated over long time spans. In the Northeast Channel, their parabolic colony form was observed to face into the out-flowing current, presumably to maximize the capture of food particles.

Growth

Based on counting the rings in cross-sections of colony bases, the oldest *Primnoa resedaeformis* colony observed was 61 years (Mortensen and Buhl-Mortensen 2005b). The relationship between height and age indicated an average growth rate of 1.7 cm/y for *P. resedaeformis*. X-ray images of skeletal sections of *Paragorgia arborea* showed clear growth bands but since it was not clear what time scales these bands indicated they could not be used for ageing. However, analysis of the time series photographs of a *P. arborea* colony at a depth of 50 m in Norway indicated a growth rate between 2.2 and 4.0 cm/y. Two much larger colonies of *P. arborea* have been reported by others. A colony on the order of 3 m high was collected in the Flemish Pass east of St. John’s at a depth of 588 m during a DFO groundfish survey (Fig. 1). Unfortunately the exact dimensions were not recorded. In addition, a 4 m colony was recently reported from New Zealand which was radiocarbon dated to be 400 +/- 100 years old (Dennis Gordon, personnal communication) which gives an average growth rate on the order of 1 cm/y. Assuming an average growth rate of 2 cm/year, it appears that the largest *P. arborea* colony measured in this study (180 cm in height) was at least 90 years old.

Behaviour

Live specimens of *Flabellum alabastrum*, *Duva florida*, *Anthomastus grandiflorus*, *Primnoa resedaeformis*, *Keratoisis ornata*, *Acanella arbuscula*, *Acanthogorgia armata*, and *Paragorgia arborea* were successfully collected by ROPOS and Videograb and transported back to BIO. *Duva florida* and *Flabellum alabastrum* turned out to be the easiest taxa to maintain in aquaria. Accidents in the lab (stopped water supply, malfunctioning thermostat, loose lines, etc.) and outbreaks of diseases killed most specimens but some survived for over a year. This experience indicates that it is feasible to conduct experiments on deep-water corals if healthy specimens can be obtained, especially *Duva florida* and *Flabellum alabastrum*. Larger colonies demand larger water volume and strong currents. Experience from different aquaria around the world (ie. Bergen Aquarium and Okinawa Aquarium) also indicates that deep-water gorgonians are difficult to maintain over a long periods.

Laboratory observations were made on the behaviour of *Duva florida, Flabellum alabastrum* and *Anthomastus grandiflorus*, in particular patterns in body extension and contraction. The results indicate that there are differences in feeding behaviour and that the ability to handle food particles of different size seems to be related to the anatomy of the polyps. One observation of note is the ability of *Flabellum alabastrum* to expand its body size more than ten times. This behaviour may be related to food uptake and physiology, or it may represent a way of escaping an area by increasing buoyancy and drag and moving with the bottom current. It was also observed in the field. *Flabellum alabastrum* was also observed to move slowly, leaving tracks in the sediment, but the mechanism for doing this is not understood. Periodicity in the respiration rate of *Flabellum alabastrum* was also measured. In time, these various laboratory observations of coral behaviour will be summarized in a scientific paper (see Appendix 2).

FAUNA ASSOCIATED WITH DEEP-WATER CORALS

Deep-water corals provide structural habitat that can be used by other species. This includes the surface of living and dead corals, cavities inside dead skeletons and the spaces between coral branches. Branches can reach up into stronger currents above the benthic boundary layer and feeding advantages are shared with attached filter-feeding organisms. Associated species can also feed on detritus and micro-organisms trapped in coral mucous.

Invertebrates

Literature Review

Buhl-Mortensen and Mortensen (2004b) have reviewed the scientific literature for information on invertebrate species associated with alcyonarian, gorgonian, scleractinian and antipatharian deep-water corals. To date, more than 980 associated species have been recorded around the world. Of these, 113 (11%) can be characterized as symbionts of which only 30 are obligate (i.e. specific to corals). Of these obligate species, 53% are parasites and 47% are commensals. Most of the parasites are endoparasites. There are few clear examples of mutualistic symbiotic relationships with deep-water corals. Known symbionts of shallow tropical and deep-water corals are compared in Table 13.

Table 13. Comparison between shallow tropical and deep-water corals of the percent composition of symbiotic species belonging to different taxa. From the review by Buhl-Mortensen and Mortensen (2004c).

Taxon	Shallow Water	Deep Water
Foraminifera	0	2
Porifera	1	0
Cnidaria	3	7
Plathyhelminthes	0	0
Polychaeta	5	20
Sipuncula	0	0
Pycnogonida	0	1
Cirripedia	5	27
Copepoda	34	3
Tanaidacea	0	1
Amphipoda	1	7
Isopoda	0	3
Decapoda	29	11
Gastropoda	15	4
Bivalvia	5	3
Ophiuridea	2	12
Asteroidea	0	2
Holothuridea	0	0
Total number of species	311	113

The number of species is substantially less for deep-water corals than for shallow-water corals (112 compared to 311). Polychaeta, Cirripedia, and Ophiuroidea appear to be more common in deep-water corals while Copepoda, Decapoda and Gastropoda appear to be more common in shallow-water corals. The highest number of symbiotic species was found associated with gorgonians (65), followed closely by scleractinians (53).

A possible reason to why obligate symbionts are more common for shallow water corals could be that the food supply in shallow water coral reefs is mainly produced within the habitat, with the corals' production as an essential part. The deepwater corals and their associated species receive their food mainly through advection from sources outside the coral habitat, and specialisations in feeding strategies are not directed by the corals to the same extent.

Collected Corals

A total of 114 invertebrate species and 3915 individuals were recorded from 25 specimens of *Paragorgia arborea* and *Primnoa resedaeformis* collected by ROPOS, Videograb and otter trawl from five areas in Atlantic Canada ranging from the Northeast Channel to the Davis Strait (Buhl-Mortensen and Mortensen 2005). The fauna associated with *P. resedaeformis* was more diverse and abundant than that associated with *P. arborea* (Table 14). The taxonomic composition of associates was different for the two gorgonian species (Fig. 10, Table 15). This was most pronounced for the copepods which dominated the fauna on *P. arborea*, and hydroids which were more abundant on *P. resedaeformis*. Rarefaction analysis indicated that many more associated species are still to be found. A large number of faunal groups was found (Table 15). The numbers of species and individuals were significantly correlated with coral morphology (e.g. number of branches, wet weight, percent exposed skeleton). Crustaceans dominated the fauna, contributing 46% of the total number of individuals and 26% of the total number of species. Two coral microhabitats were identified: young and live parts of colonies and old parts with deposits, and exposed skeleton. Most of the associated fauna was found in the latter microhabitat. Sessile hydroids, anemones and molluscs were more abundant on *P. resedaeformis* and were attached to exposed skeleton. Parasitic copepods were more common on *P. arborea*. The basket star *Gorgonocephalus lamarckii* was found on the outer branches of *P. arborea* in high current environments. The shrimp *Pandalus propinquus* was found within colonies of both species.

In the Northeast Channel, a parasitic colonial zoanthid anemone was the most common sessile epibiont observed on *Primnoa resedaeformis* (Mortensen et al. 2005). On average, it covered about 60% of the surface of the 28 infected colonies, but one third of the colonies were entirely covered. Hydroids were also frequently found on *P. resedaeformis* (represented with 12 species), but were less common on *P. arborea* (three species). Henry (2001) reports that thirteen hydroid species were found on four coral specimens collected off Atlantic Canada.

Table 14. Abundance, number and diversity (H') of species associated with *Paragorgia arborea* and *Primnoa resedaeformis* collected off Atlantic Canada. From Buhl-Mortensen and Mortensen (2005).

Taxon	Sample		Number of Individuals	Number of Species	Diversity (H')
Paragorgia arborea	PaC1		628	3	0.71
	PaC2		229	9	1.84
	PaC3		102	11	1.82
	PaC4		57	4	0.49
	PaB1		46	4	1.15
	PaB2		24	3	0.86
	PaB3		9	5	1.15
	PaB4		29	7	1.55
	PaB5		33	11	1.82
	PaB6		2	2	0.69
	PaB7		0	0	0
	PaB8		104	18	2.16
	PaB9		1	1	0
		Sum	1264	47	2.17
Primnoa resedaeformis	PrC1		722	61	3.4
	PrC2		263	17	1.44
	PrC3		209	16	1.86
	PrC4		176	16	1.82
	PrC5		134	18	2.02
	PrC6		399	27	2.69
	PrB1		1	1	0
	PrB2		0	0	0
	PrB3		0	0	0
	PrB4		490	26	2.39
	PrB5		71	16	2.07
	PrB6		186	23	2.4
		Sum	2651	97	3.54

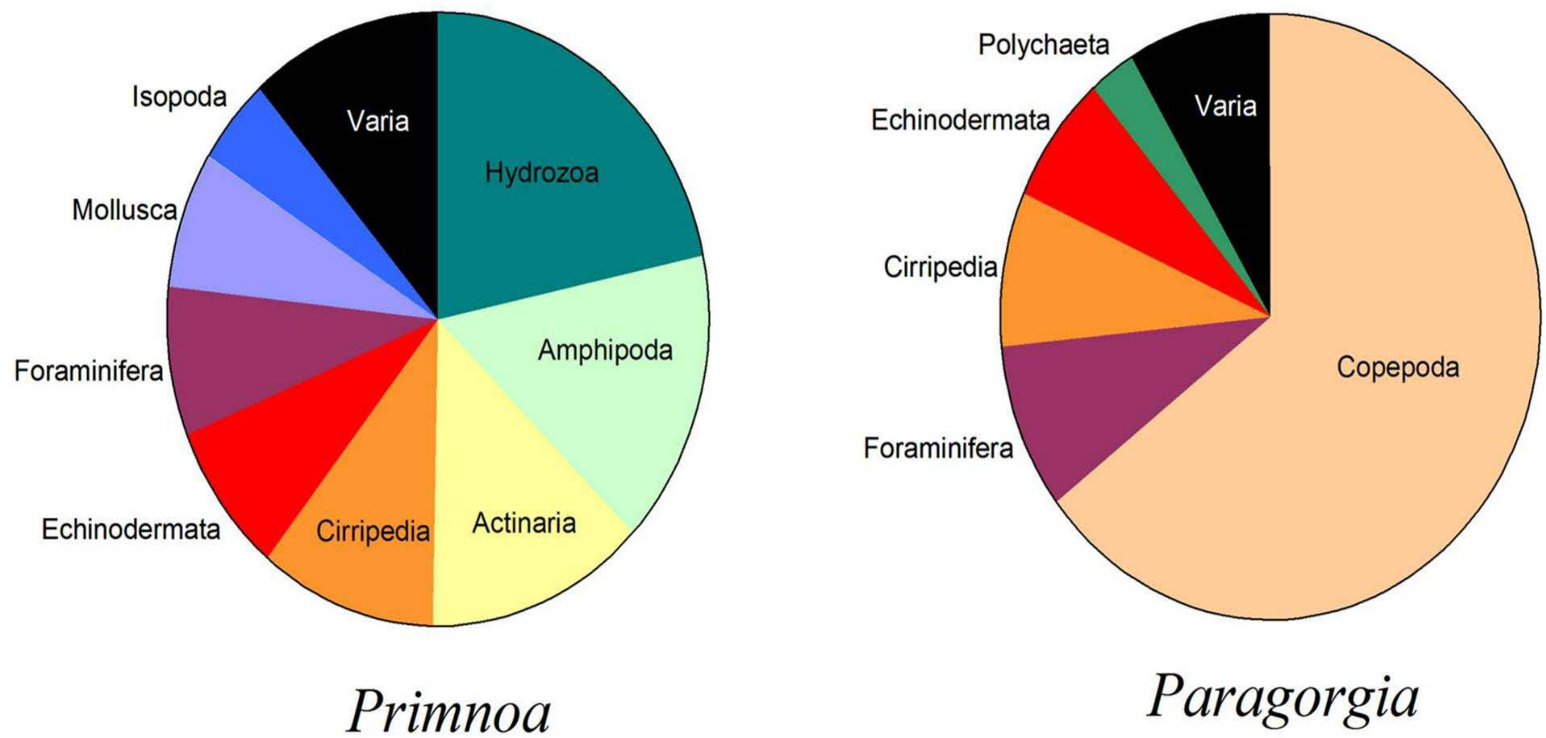

Figure 10. The relative abundance of different taxa of associated invertebrate fauna on *Primnoa resedaeformis* and *Paragorgia arborea*.

Table 15. The number of taxa and individuals within different faunal groups found associated with *Paragorgia arborea* and *Primnoa resedaeformis* collected in Atlantic Canada. From review by Buhl-Mortensen and Mortensen (2005).

Number of Species				Number of Individuals			
P. arborea		*P. resedaeformis*		*P. arborea*		*P. resedaeformis*	
Foraminifera	11	Foraminifera	17	Copepoda	814	Hydroida	578
Polychaeta	7	Amphipoda	14	Foraminifera	113	Amphipoda	406
Amphipoda	6	Mollusca	13	Cirripedia	102	Actinaria	352
Echinodermata	4	Hydroida	12	Echinodermata	88	Cirripedia	274
Porifera	1	Polychaeta	10	Polychaeta	37	Echinodermata	216
Mollusca	3	Echinodermata	7	Actinaria	31	Foraminifera	206
Hydroida	3	Actinaria	5	Hydroida	28	Mollusca	190
Copepoda	3	Octocorallia	4	Amphipoda	20	Isopoda	126
Actinaria	2	Cirripedia	3	Mollusca	15	Polychaeta	84
Tanaidacea	1	Bryozoa	2	Acaria	4	Acarina	68
Ostracoda	1	Copepoda	2	Ostracoda	3	Copepoda	41
Isopoda	1	Decapoda	2	Decapoda	3	Ostracoda	37
Decapoda	1	Porifera	2	Bryozoa	1	Octocorallia	29
Cirripedia	1	Isopoda	1	Isopoda	1	Bryozoa	27
Bryozoa	1	Ostracoda	1	Tanaidacea	1	Pycnogonida	9
Acaria	1	Acarina	1	Porifera	3	Decapoda	4
		Pycnogonida	1			Porifera	4
Sum	47		97		1264		2651

Suction Samples

Seventeen species of associated crustaceans were identified in seven colonies of *Paragorgia arborea* and eight colonies of *Primnoa resedaeformis* sampled with the suction sampler on ROPOS in the depth range of 330-500 m in the Northeast Channel (Buhl-Mortensen and Mortensen 2005). The *P. arborea* fauna was richer than the *P. resedaeformis* fauna in both number of species and abundance. Amphipods dominated the fauna but isopods and cirripeds were also common. The most strongly associated crustaceans were two parasitic copepods belonging to a family which is also found on tropical gorgonians and are most likely obligate associates. Shrimp also occurred frequently and most likely seek protection from predation among coral branches. The numerical dominance of amphipods and parasitic copepods is similar to observations made on tropical shallow-water gorgonians but the species richness is higher.

Many of the associated taxa are also found on tropical gorgonians but the deep-water gorgonians lack the diverse decapod and gastropod fauna of their tropical counterparts. The richness of species associated with deep-water gorgonians appears to be higher than reported for tropical shallow-water gorgonians. In contrast to tropical shallow-water gorgonians, deep-water gorgonians have very few obligate symbionts. Nevertheless, several of the species are rare in other habitats and some have been recorded on the same and other gorgonian species in earlier studies. There was a clear difference in the faunal composition of samples collected with different gear types (Fig. 11).

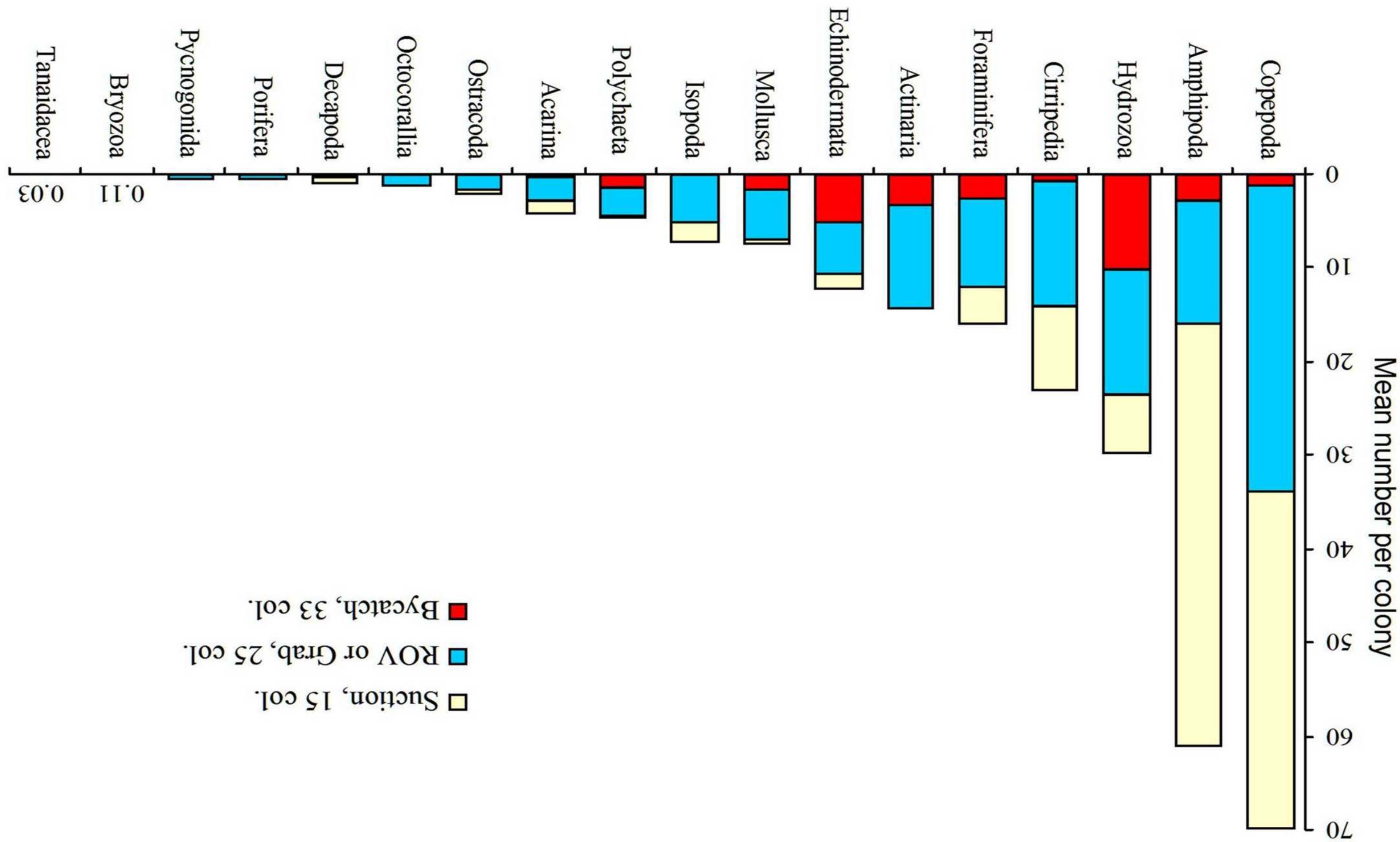

Figure 11. The mean number of individuals of associated invertebrate species per colony within different taxa for the three different sampling methods.

New Species

A new genus and species of a gall-forming parasitic copepod (*Gorgonophilus canadensis*) was discovered on specimens of *Paragorgia arborea* collected in the Northeast Channel by ROPOS and in the Davis Strait by a groundfish trawl survey (Buhl-Mortensen and Mortensen 2004c). Infection of this endoparasite seems to have little effect on the host. A new species of pedunculate barnacle (*Heteralepas cantelli*) was discovered on a specimen of *Primnoa resedaeformis* collected by otter trawl at a depth of about 500 m on the Scotian Slope (Buhl-Mortensen and Newman 2004). This is the most northern record of this genus.

The gorgonian *Trachythela rudis* was observed for the first time off Nova Scotia. It occurred as an epizoic on a *Primnoa resedaeformis* skeleton. Previously, it is known from the fishing banks off Newfoundland (Verrill 1922; Deichmann 1936).

Fish

Various taxa of fish are commonly seen associated with corals in the video imagery. The most common is the redfish (*Sebastes* spp.) which is widely distributed in deep water through out Atlantic Canada, including sites without abundant corals. In the Northeast Channel, redfish were almost four times as common in video sequences with corals than in sequences with boulders but not corals (Mortensen et al. 2005). Twelve taxa of fish were observed along the video transects in the Gully (Mortensen and Buhl-Mortensen 2005a). Like the Northeast Channel, the most common species was redfish (*Sebastes* spp.) which was found on 68% of the transects. The second most common species was the long-finned hake (*Urophycis chesteri*) which was found on 51% of the transects. Redfish were also abundant at the site of the *Lophelia pertusa* reef complex at the Stone Fence but the relationship with corals was not significant, perhaps because of the small size of colonies compared to the Northeast Channel. Overall, the correlation between redfish and coral abundance, as determined by analysis of video (scale less than 25 m) was strongest in the Northeast Channel ($R^2 = 0.59$, $p < 0.005$).

DAMAGE BY FISHING GEAR

It is clear that fishing gear coming into contact with the seabed has the potential to damage corals, especially the larger species. Corals are commonly brought onboard as bycatch during commercial fishing operations and research trawl surveys. Damaged corals can also be left behind out of sight on the seabed. The significance of this damage is not clear and currently a matter of debate. Coral communities can probably tolerate a low magnitude and frequency of damage but their slow growth rates (just a few cm/y) means that recovery times will be long (tens to hundreds of years). The critical levels of damage and the recolonization time are not known, but observations indicate that recurring damage may accumulate over time and that recovery will be slow.

Potential damage to deep-water corals by bottom contacting fishing gear can be estimated by comparing the spatial distribution of fishing effort to that of corals. A high degree of overlap indicates increased likelihood of significant impacts. All types of bottom contacting gear have the potential of causing impacts but the relative impacts appear to be greatest for bottom trawls (Chuenpagdee et al. 2003). More detailed information on impacts has been obtained by careful analysis of the video footage collected in this project.

Northeast Channel

The Northeast Channel is an important fishing area targeted by otter trawling, longline and gillnet fleets. Longline activity is widespread while otter trawling and gillnet activity is concentrated on the Georges Bank side of the Channel. Invertebrate fisheries are limited to date and generally are shallower than 300 m. As reported by Mortensen et al. (2005), signs of fishing impact were visible as broken live corals, tilted corals and scattered skeletons. Broken or tilted corals were observed on 29% of the transects and were not concentrated in any particular area. In total, 4% of the observed colonies were damaged. A higher percentage of *Paragorgia arborea* colonies was damaged compared to *Primnoa resedaeformis* (7.9% versus 3.4%). This is most likely due to its larger size and less flexible skeleton. It appears that damage may make corals more susceptible to parasites since a parasitic anemone was more common on damaged colonies of *P. resedaeformis* than intact ones. Lost longlines were observed loose on the seabed or entangled in corals on 37% of the transects. Tracks on the seabed, either from longline anchors or parts of otter trawl gear, were present along three transects, while lost gillnets were observed along two transects. With one exception, longlines were only found on transects where coral were present.

Scotian Slope

In general, the distribution of trawling recorded by the observer program indicates that the Scotian Slope is quite heavily fished (Kulka and Pitcher 2001). However, no signs of damage to corals were observed in the video footage along the transects surveyed (Fig. 1). This is probably because the dominant species are small, free-living cup corals which are less prone to damage from fishing gear than the large, attached gorgonians and *Lophelia pertusa* reefs. However, the chances of observing damage are probably greater in canyons (e.g. Dawson, Logan, Shortland, and Haldiman) along the Scotian Slope where larger corals should be more common.

The Gully

Much fewer indications of fisheries damage to corals were observed in the Gully compared to the Northeast Channel and Stone Fence. Few signs of fishing were observed, just a few trawl tracks and one corroded lost wire from a trawl. However, tilted seapens and seapen skeletons were quite common on the sides of the Gully in the outer part. Spatial analysis of observer data by Kulka and Pitcher (2001) indicates that the general area of the Gully was heavily fished with otter trawls during the 1980s and early 1990s but that trawling effort has dropped significantly since then with very little activity in 1998-2000. The major fishery at this time is longline for halibut. It is thought that canyons in general are naturally protected to some degree against bottom trawling because of their rugged topography.

Stone Fence

The state of the *Lophelia pertusa* reef formations at the Stone Fence indicates an accumulated impact from fishing gear. All live colonies were either small or clearly broken in an unnatural way. When *L. pertusa* grows to a certain critical size it breaks naturally as a result of great weight and weakening processes from boring organisms (Wilson 1979). Fragmentation as result of this natural process is easily distinguished from physical disturbance from a bottom trawl. Natural fragmentation cause less sediment infill in the skeletal matrix and occur more randomly scattered. Furthermore, corals damaged by trawling is often accompanied by scars in seabed caused by the trawl doors or the gear. The rubble zone normally surrounding a *L. pertusa* reef was larger at the Stone Fence than similar sized reefs off the Norwegian coast. In many cases clear signs of disturbance in the rubble zone were present as unusual amounts of pale grey skeletons. Normally, *L. pertusa* skeletons on the seabed exposed to the water have a brown coating of manganese oxide. In addition to the evidence of fishing impact on *L. pertusa*, gorgonians showed signs of disturbance in the form of their small size and unnatural occurrence on the sides of and underneath boulders. Many cobbles and boulders showed signs of being overturned (i.e. clean surface atop and fouling underneath). A fragment of a trawl net was also found. Spatial analysis of observer data by Kulka and Pitcher (2001) indicates that the general area of the *L. pertusa* reef was regularly trawled between 1980 and 2000 although there is a suggestion that effort was lighter the last few years. Current fisheries operating in the area are otter trawling for redfish and anchored longline for halibut. Observer effort and landings data from 1998-2003 indicate that both fisheries overlapped the area of the reef. More details are given in a paper about to be submitted (see Appendix 2).

APPLICATION OF RESULTS

Publications

Revised identification sheets for corals most likely captured by fishing gear species were prepared and widely distributed (see Appendix 1). The results of this project are gradually being reported in the scientific literature. To date, 16 papers are published or in press in international journals and three are in preparation (Appendix 2). Several posters summarizing results have been prepared and presented at numerous conferences and workshops in Canada and abroad.

Presentations

A large number of presentations on the results of this project have been made as they became available. These have included briefings to CAPP (Canadian Association of Petroleum Producers), briefings to the DFO Fisheries Roundtable, presentations to DFO oceans and fisheries management personnel, lectures at scientific conferences and universities, and participation in workshops organized by conservation organizations. Many of these presentations were accompanied with summary videos of corals and their habitats prepared by BIO Technographics. Numerous requests for video footage and photos of corals have been received and fulfilled.

Coral Conservation

There is a strong international interest in coral conservation. Several countries including Norway, the UK, Ireland, the USA and Australia have established closures to protect deep-water corals from fishing and hydrocarbon activities. A draft coral conservation strategy for Atlantic Canada has been developed by the World Wildife Fund (Gass 2003).

For several years, some sectors of the fishing industry and environmental organizations have proposed specific zones for deep-water coral protection in the Northeast Channel. In early 2002, DFO and the fishing industry formed a working group to consider coral protection. After reviewing the preliminary results of the video surveys, DFO proposed boundaries for a coral conservation area centered on Romeys Peak because of its high abundance of gorgonians. A fisheries assessment was conducted using available data and discussions with the working group and at a public meeting lead to a greater understanding of the overlap between fishing activities and coral abundance. Adjustments were made to the design of the conservation area taking into consideration the concerns of fishing organizations. A coral conservation area, 424 km^2 in size, was formally established by DFO in June 2002 (Mortensen et al. 2005) and slightly modified in 2003. With the exception of 10% of the area which is open to longline gear, the entire area is closed to all bottom fishing gear.

The results of this project have confirmed earlier observations (Breeze et al. 1997, MacIsaac et al. 2001) that the Gully is indeed a special habitat for deep-water corals. While the average abundance of corals is less than in the Northeast Channel, the species diversity is much greater (Table 8). The importance of corals in the Gully has played a role in the design of the large Marine Protected Area (2364 km^2) that was formally announced in May 2004.

The discovery of the *Lophelia pertusa* reef complex at the Stone Fence, heavily damaged by fishing activity, led to immediate discussions and meetings regarding establishing a coral conservation area. The need for such a closure to prevent further damage and allow recovery was recognized by all parties, including the fishing industry. After considerable consultation, a 15 km^2 coral conservation area centered over the reef complex was established by DFO in June 2004 (Department of Fisheries and Oceans 2004).

Advice

The knowledge gained during this study has been widely used by DFO scientists in providing scientific advice on a broad range of fisheries and habitat management issues dealing with corals, including the potential impacts of oil and gas exploration/development and bottom-fishing gear.

Media

Throughout this project, there has been considerable media interest and a large number of interviews have been given. This has resulted in extensive national coverage in print, radio and television media. As a result, the Canadian public is now much more knowledgeable about the extent, importance and vulnerability of deep-water corals.

Website

A website describing the structure and some preliminary results of this research project was constructed and posted under the Centre for Marine Biodiversity. The full address is http://www.marinebiodiversity.ca/CoralWebsite/Homepagecorals.htm.

Displays

A large display of gorgonians and associated species from the Northeast Channel was prepared and is on permanent view at the Bedford Institute of Oceanography.

FUTURE PLANS

As is evident from the results presented in this report, this three-year research project (2001-2003), funded by ESRF and DFO, has produced a wealth of new information on deep-water corals in Atlantic Canada. However, there still is much to be learned about these fascinating organisms, perhaps most importantly continuing work on their distribution below 500 m and in areas not yet surveyed with video equipment. Unfortunately, due to resource limitations, at this time DFO has no concrete plans for field programs in 2004 and beyond. However, a MOU was recently signed between DFO and DND to use the DSIS ROV on a DFO vessel, and hopefully this will result in new sampling opportunities for deep-water corals. In the meantime, DFO will still collect and archive coral samples from the groundfish surveys and data from the Fisheries Observer Program. In addition, using the results of this project, a summary data base on coral distribution (e.g. taxon, location, depth) in Atlantic Canada is being prepared and will be made available to anyone interested.

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APPENDIX 1

IDENTIFICATION SHEETS FOR CORALS IN ATLANTIC CANADA
MARINE ENVIRONMENTAL SCIENCES DIVISION
BEDFORD INSTITUTE OF OCEANOGRAPHY
DEPARTMENT OF FISHERIES AND OCEANS

2003

Thirty-six species of deep-water corals have been reported to occur in Atlantic Canada. Six species of soft corals (alcyonaceans), eleven species of horny corals (gorgonians), eleven species of stony corals (scleractinians), one species of black coral (antipatharians), and eight species of seapens (pennatulids). These sheets, designed to improve the identification of corals at sea, include the most common species likely to be captured with fishing gear. They build upon an earlier version developed by the Ecology Action Centre. Numbers for each taxa are the identification codes used in the Maritimes Region.

For further information contact:

Nova Scotia:
Cynthia Bourbonnais (Bedford Institute of Oceanography) 902-426-2791
Kevin MacIsaac (Bedford Institute of Oceanography) 902-426-2504

Newfoundland:
Kent Gilkinson (Northwest Atlantic Fisheries Centre) 709-772-4718
Evan Edinger (Memorial University) 709-737-3233

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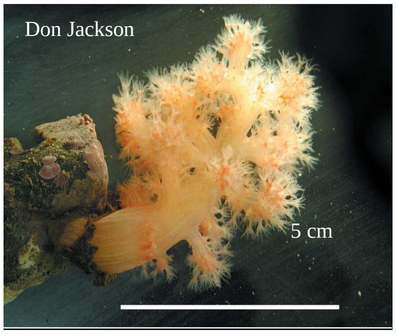
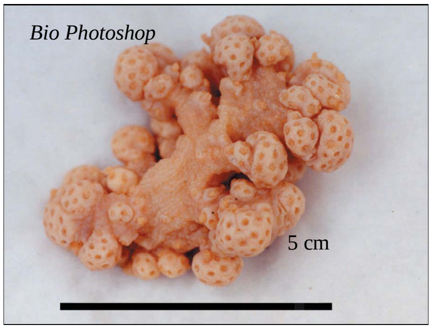
Centre for Marine Biodiversity (CMB) Website:
http://www.marinebiodiversity.ca

DFO Coral Website
http://www.marinebiodiversity.ca/CoralWebsite/Homepagecorals.htm

DFO Backgrounder on Coral Research and Conservation
http://www.mar.dfo-mpo.gc.ca/communications/maritimes/back02e/B-MAR-02-(5E).html

Marine Invertebrate Diversity Initiative (MIDI) Website
http://www.fundyforum.com/MIDI/



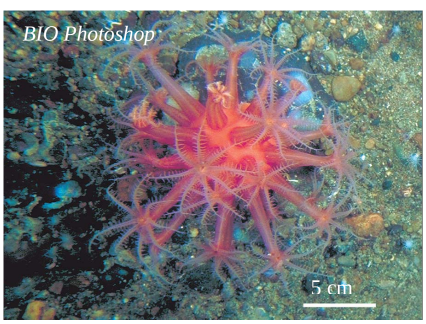


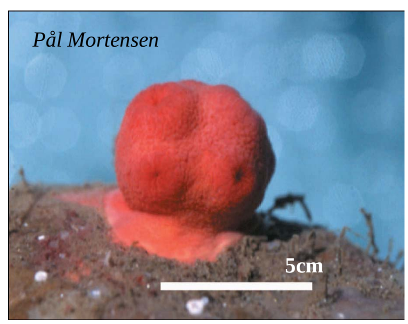
G*ersemia rubiformis* (Sea Cauliflower, Strawberries, Red Soft Coral)(Alcyonacean) (8324)

Appearance: Shaped like broccoli when relaxed, like cauliflower when retracted. Soft tissue with no skeleton.
Height: Usually less than 15 cm.
Colour: Red, pink, orange, or yellow
Habitat: Attached to a variety of stable substrates. In sandy areas attached to shells and gravel. Depth range about 3 to possibly over 1000 m (547 fathoms). Can be common on fishing banks, especially on sandy
bottoms.

Capnella spp. (= *Duva* spp.) (Sea Cauliflower, Strawberries) (Alcyonacean) (8327)

Appearance: Shaped like broccoli. When fully retracted, resembles a truffle mushroom. Soft tissue with no skeleton.
Height: Usually less than 25 cm.
Colour: Light red, brown, blue or white
Habitat: Hard substrate, often attached to gravel on muddy seabeds. Depth range about 200 m (109 fathoms) to at least 1500 m (820 fathoms).



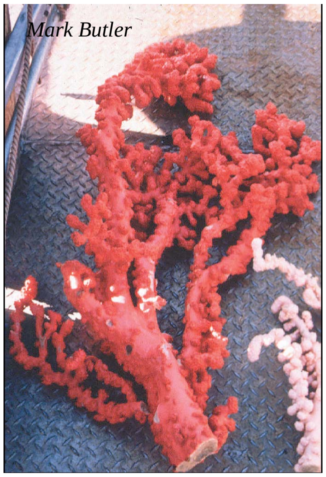


Anthomastus grandiflorus (Alcyonacean) (8328)

Appearance: Round mushroom-shaped colonies with large polyps (usually retracted).
Height: Usually less than 10 cm.
Colour: Red
Habitat: Hard substrate, often attached to gravel on muddy seabeds. Usually deeper than 300 m (164 fathoms).

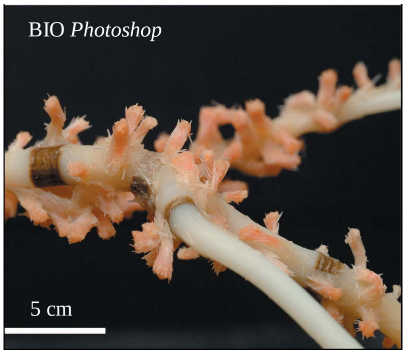
Primnoa resedaeformis (Sea Corn) (Gorgonian) (8322)

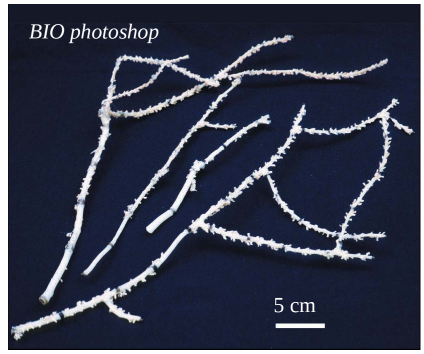
Appearance: Densely branched colonies giving the appearance of small trees or bushes. Stiff but flexible skeleton. Polyps surrounded with small scales are situated on the skeleton.
Height: Up to 1 m
Colour: Orange or salmon pink tissue. Dead colonies lack polyps and the skeleton is usually pale gray (sometimes gold, brown or black).
Habitat: Attached to gravel and bedrock, especially in channels and canyons. Usually deeper than 200m (109 fathoms) Very common in the Northeast Channel between Browns and Georges Bank (i.e. Coral Conservation Area).



Paragorgia arborea (Bubble Gum Coral, Rubber Trees) (Gorgonian) (8323)

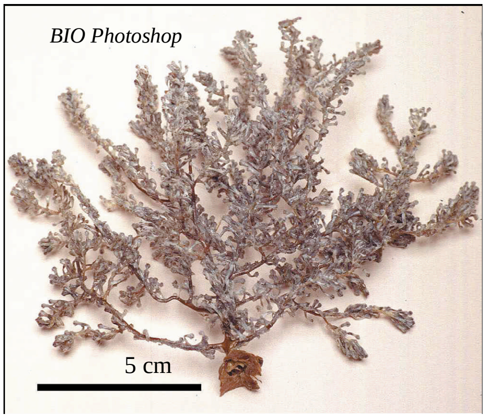
Appearance: Tree-like. Large colonies are commonly fan-shaped. Thick main stem with branches. Brittle and easily broken. Spongy skeleton.
Height: Up to at least 3 m (with unconfirmed reports of greater height)
Colour: White, light tan to dark red
Habitat: Attached to gravel, especially in channels and canyons. Usually deeper than 300 m (164 fathoms). Common in the Northeast Channel (i.e. Coral Conservation Area).

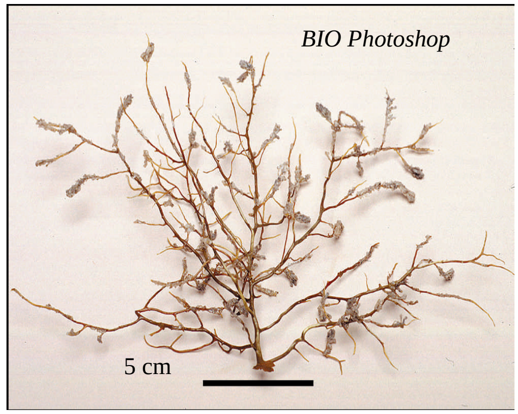




Keratoisis ornata (Gold-banded Coral, Bamboo Coral, Birch Trees) (Gorgonian) (8325)

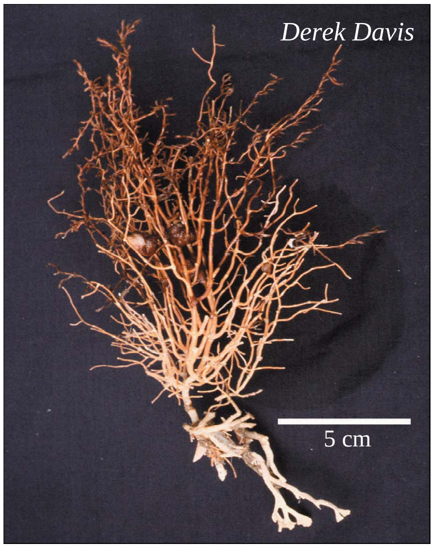
Appearance: Stiff slender branching colonies. Fewer branches than most other species. White calcified skeleton with joints about every 6-7 cm.
Height: Up to 1.3 m
Colour: Skeleton is white with gold or yellow joints. Pale pink to pale orange polyps.
Habitat: Grows attached to gravel on muddy seabeds, especially in channels and canyons. Usually deeper than 300 m (164 fathoms). Frequently observed along the western side of the Sable Island Gully.





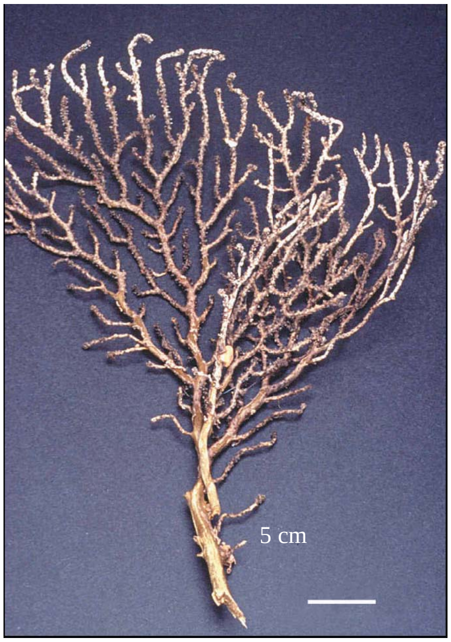
Acanthogorgia armata (Gorgonian) (8326)

Appearance: Branched colonies, flexible and resembling a small bush. Polyp houses sticking out along the branches.
Height: Most specimens less than 20 cm in height but can reach 50 cm.
Colour: Dirty white, yellow or salmon
Habitat: Muddy or sandy mud bottom usually deeper than 300 m (164 fathoms), but appears shallower on Misaine Bank. Can be very abundant locally.



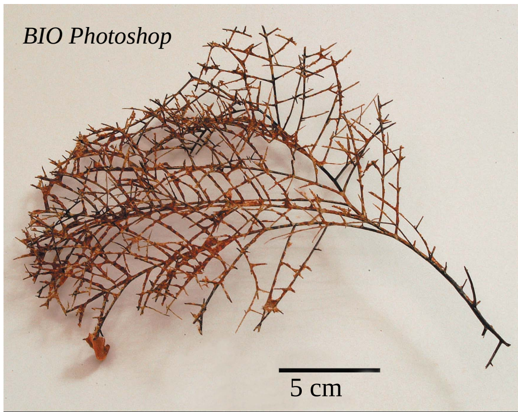
Acanella arbuscula (Gorgonian) (8329)

Appearance: Small branched colonies with segmented branches apparent through the thin and transparent tissue. Base has anchor-like, branched structure for anchoring in soft sediments (these may be absent if damaged). Colonies are stiff but delicate.
Height: Usually less than 15 cm.
Colour: Salmon or orange. Anchor is usually white.
Habitat: Muddy or sandy mud bottom usually deeper than 300 m (164 fathoms), but appears shallower on Misaine Bank. May be locally abundant.



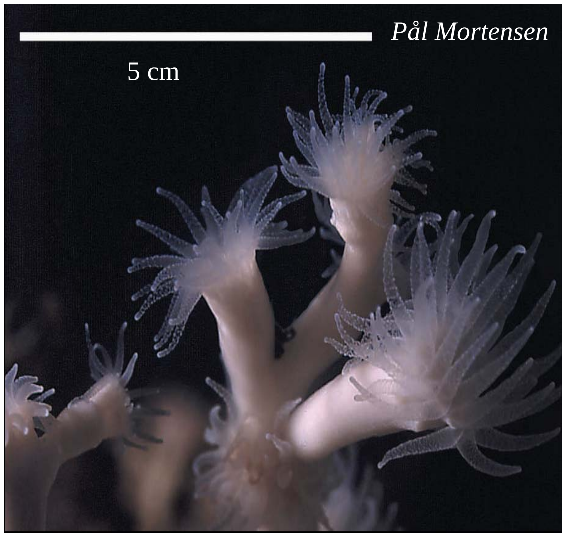
Paramuricea spp. (Black Coral)(Gorgonian) (8333)

Two species of *Paramuricea* occur but are hard to distinguish without a microscope.
Appearance: Fan-like. Branches arranged in loose and irregular pattern in one plane. Flexible skeleton.
Height: Up to 50 cm high.
Colour: Orange, yellow or salmon when alive. Turns greyish or black out of water.
Habitat: Attached to gravel and bedrock below 400 m (219 fathoms).



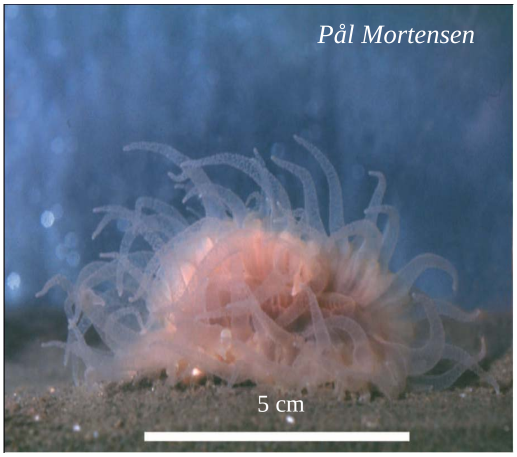
Bathypathes sp. (Antipatharian) (8334)

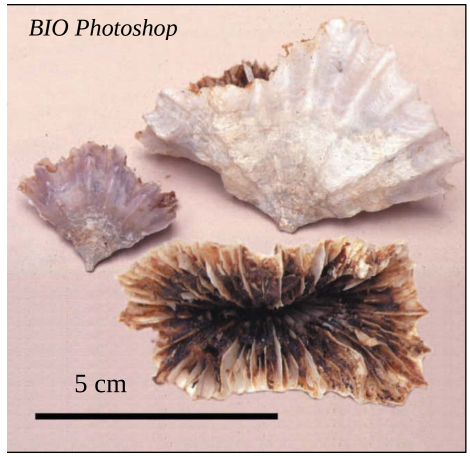
Appearance: Many stiff, narrow and thorny branches.
Height: 15-30 cm
Colour: Orange to light brown tissue over a black skeleton.
Habitat: Reported off Newfoundland to at least 1000 m (549 fathoms).



Lophelia pertusa (Spider Hazard) (Scleractinian) (8331)

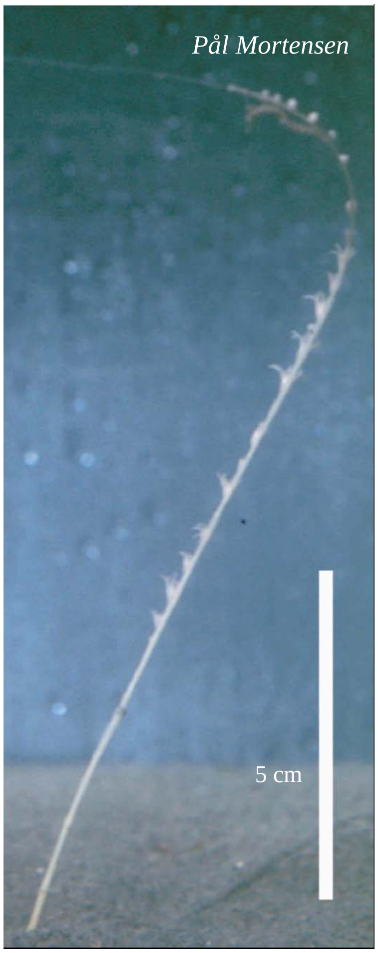
Appearance: Hard skeleton with 1-cm thick branches. The branches often cross and fuse together forming a complicated network with open spaces inside.
Height: Colonies up to 2 m. Can form large reefs or mounds up to 30 m tall consisting of numerous neighboring colonies. Fragments collected are usually smaller than 30 cm.
Colour: White skeleton. White or orange pink polyps. Pieces of dead skeleton are usually gray.
Habitat: Occurs mostly at depths between 200 and 1000 m (109 and 547 fathoms).





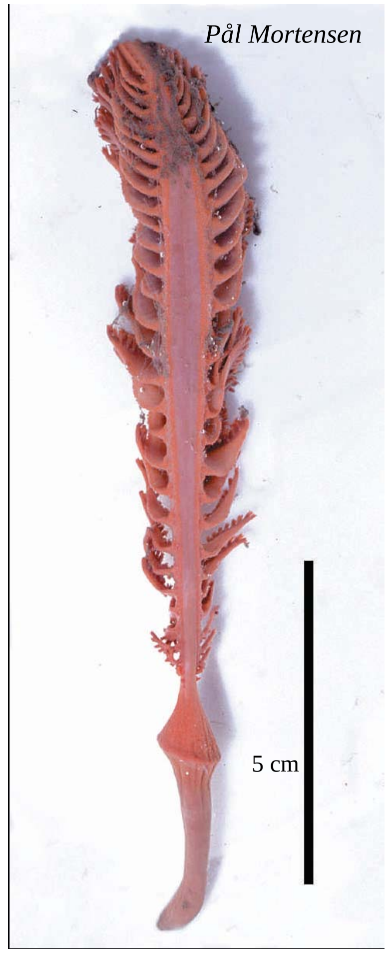
Flabellum spp. (Cup Coral) (Scleractinian) (8335)

Three species of *Flabellum* occur but are hard to distinguish.
Appearance: Cup-shape, hard skeleton. Thin ridges on the inside of the cup.
Height: Usually less than 7 cm.
Colour: White skeleton. Tissue is transparent, pink or yellow.
Habitat: Unattached on muddy or sandy mud seabeds deeper than 300 m (164 fathoms). Most common along the continental slope. Can be quite abundant locally.



Radicipes gracilis (Gorgonian)

Appearance: Whip-like. Unbranched. Slightly spirally twisted. Base has a branched structure for anchoring in soft sediments. Photo shows young specimen.
Height: Usually less than 50 cm in height.
Colour: White or greyish.
Habitat: Muddy or clayey bottom usually deeper than 400 m (219 fathoms).



Seapens (Pennatulid) (8318)

Numerous species occur but are hard to distinguish by the non-specialist.
Appearance: Feather-like. If visible, the foot is fleshy without branches.
Height: Up to 30 cm.
Colour: Various colours including pink, red, yellow and brown.
Habitat: Anchored in soft bottoms. About 100 m (55 fathoms) to more than 1000 m (547 fathoms).

APPENDIX 2

Project Publications

Published

Buhl-Mortensen, L. and P.B. Mortensen. 2004. Crustaceans associated with the deep-water gorgonian corals *Paragorgia arborea* (L., 1758) and *Primnoa resedaeformis* (Gunn. 1763). Journal of Natural History 38: 1233-1247.

Buhl-Mortensen, L. and P.B. Mortensen. 2004. Symbiosis in deep-water corals. Symbiosis 37: 33-62.

Buhl-Mortensen, L. and P.B. Mortensen. 2004. *Gorgonophilus canadensis* n. gen., n. sp. (Copepoda: Lamippidae), a gall forming endoparasite in the octocoral *Paragorgia arborea* (L., 1758) from the Northwest Atlantic. Symbiosis 37: 155-168.

Buhl-Mortensen, L. and P.B. Mortensen. 2005. Distribution and diversity of species associated with deep-sea gorgonian corals off Atlantic Canada. In: Freiwald, A. and J.M. Roberts (eds), Cold-water corals and ecosystems, Springer-Verlag, pp. 849-879.

Buhl-Mortensen, L. and W.A. Newman. 2004. A new pedunculate barnacle (Cirripedia: Heteralepadidae) from the Northwest Atlantic Ocean. Proceedings of the Biological Society of Washington. 117: 385-397.

Gass, S.E. 2002. An assessment of the distribution and status of deep-sea corals in Atlantic Canada by using both scientific and local forms of knowledge. Master's Thesis, Dalhousie University, 186 p.

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Gass, S.E. and J.M.H. Willison. 2005. An assessment of the distribution of deep sea corals in Atlantic Canada by using both scientific and local forms of knowledge. In: Freiwald, A. and J.M. Roberts (eds), Cold-water corals and ecosystems, Springer-Verlag, pp. 223-245.

Henry, L.-A. 2001. Hydroids associated with deep-sea corals in the boreal north-west Atlantic. J. Mar. Biol. Assoc. U.K. 81: 163-164.

Henry, L.-A., E.L.R. Kenchington and A. Silvaggio. 2003. Effects of mechanical experimental disturbance on aspects of colony responses, reproduction and regeneration in the cold-water octocoral *Gersemia rubiformis*. Can. J. Zool. 81: 1691-1701.

MacIsaac, K., C. Bourbonnais, E. Kenchington, D.C. Gordon Jr. and S. Gass. 2001. Observations on the occurrence and habitat preference of corals in Atlantic Canada.

In: J.H.M. Willison et al. (eds.) Proceedings of the First International Symposium on Deep-Sea Corals, Ecology Action Centre and Nova Scotia Museum, Halifax, NS, pp. 58-75.

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

Mortensen, P.B., and L. Buhl-Mortensen. 2005. Deepwater corals and their habitats in The Gully, a submarine canyon off Atlantic Canada. In: Freiwald, A. and J.M. Roberts (eds), Cold-water corals and ecosystems, Springer-Verlag, pp. 247-277.

Mortensen, P.B. and L. Buhl-Mortensen. 2005. Morphology and growth of the deep-water gorgonians *Primnoa resedaeformis* and *Paragorgia arborea.* Marine Biology 147: 775-788.

Mortensen, P.B., L. Buhl-Mortensen, D.C. Gordon Jr., G.B.J. Fader, D.L. McKeown and D.G. Fenton. 2005. Effects of fisheries on deepwater gorgonian corals in the Northeast Channel, Nova Scotia. American Fisheries Society Symposium 41: 369-382.

Strychar, K.B., L.C. Hamilton, E.L. Kenchington, and D.B. Scott. 2004. Genetic circumscription of deep water coral species in Canada using 18S rRNA. In: Freiwald A. and J.M. Roberts (eds), Cold-water corals and ecosystem, Springer-Verlag, 679-690.

<u>In Press</u>

Buhl-Mortensen, L. & Høeg J. T. 2006. Reproduction and larval development in three scalpellid barnacles (*Scalpellum scalpellum* (Linnaeus, 1767), *Ornatoscalpellum stroemii* (M. Sars 1859) and *Arcoscalpellum michelottianum* (Seguenza 1876), Crustacea: Cirripedia: Thoracica): Implications for reproduction and dispersal in the deep-sea. Marine Biology, in press.

Mortensen, P.B., L. Buhl-Mortensen, S. E. Gass, D. C. Gordon Jr., E.L.R. Kenchington, C. Bourbonnais and K.G. MacIsaac. 2006. Deep-water corals in Atlantic Canada: A summary of ESRF-funded research (2001-2003). Final report to ESRF.

Mortensen, P.B., L. Buhl-Mortensen, and D.C. Gordon Jr.. 2006. Distribution of deep-water corals in Atlantic Canada. 10th International Coral Reef Symposium, Okinawa, Japan

In Preparation

Mortensen, P.B., D.C. Gordon Jr., L. Buhl-Mortensen and D.W. Kulka. The first direct observation of a *Lophelia pertusa* reef complex in Atlantic Canada (outer Laurentian Channel).

Mortensen, P.B., L. Buhl-Mortensen, S. Armsworthy and D.L. Jackson. Behavior and respiration of the solitary scleractinian, *Flabellum alabastrum* Moseley, 1876. 3rd Int. Deep-Sea Coral Symp., Miami, USA.