An assessment of the distribution of deep-sea corals in Atlantic Canada by using both scientific and local forms of knowledge

Susan E. Gass*, J.H. Martin Willison

School for Resource and Environmental Studies, Dalhousie University, Halifax, Nova Scotia, B3H 3J5, Canada

*Current address: Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, Oban, Argyll, PA37 1QA, UK
(susan.gass@sams.ac.uk)

Abstract. More than 27 species of deep-sea corals have been identified off Atlantic Canada but their distributions are largely unknown. Bottom trawling is recognized as a threat to deep-sea corals in Atlantic Canada but the degree of damage has not been quantified. It is difficult to assess the level of conservation required for these organisms without basic information about their distribution. This study attempts to improve our knowledge of the distribution of deep-sea corals in Atlantic Canada.

The study uses three sources of data to map the distribution of deep-sea corals in Atlantic Canada including the Canadian Department of Fisheries and Oceans (DFO) groundfish trawl surveys from 1999-2001, DFO fisheries observer records from 2000 and 2001, and local ecological knowledge of fishermen in northern Nova Scotia and Newfoundland. The results reveal that deep-sea corals are widely distributed along the edge of the continental shelf from the Gulf of Maine to the Davis Strait. The study confirms the presence of eight species including: *Acanella arbuscula*, *Acanthogorgia armata*, *Flabellum* spp., *Keratoisis ornata*, *Lophelia pertusa*, *Paragorgia arborea*, *Paramuricea* spp. and *Primnoa resedaeformis*. Significant findings from the study include: documentation of an antipatharian, an order not previously recorded in Atlantic Canada; documentation of *L. pertusa* from the Stone Fence and reported locations from Jordan Basin and the Gully; and the extension of the known ranges of *P. arborea, K. ornata*, and *Paramuricea* spp. Relatively high abundances of *P. resedaeformis* and *P. arborea* are reported from the Northeast Channel off southwest Nova Scotia and east of Cape Chidley, Labrador. The highest coral species richness is found along the edge of the continental shelf between the Gully and the Laurentian Channel at the edge of the Scotian Shelf. Fishermen reported catching the largest specimens and highest numbers of corals from the Stone Fence and also identified the Gully as an area of high coral abundance. Several fishermen reported significant changes to the seafloor on the

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eastern Scotian Shelf and the Stone Fence over the duration of their fishing careers, including a decrease in the size and number of corals they caught.

Keywords. Deep-sea coral, distribution, Atlantic Canada, local knowledge, fishery impacts

Introduction

To date at least 27 species of deep-sea corals have been identified in Atlantic Canadian waters, six Alcyonacea, 10 Gorgonacea and 11 Scleractinia (Breeze et al. 1997; Mukhida and Gass 2001). Exact locations for each species were largely unknown until the current study was completed. The majority of pre-existing distribution data were based on specimens and information provided by fishermen, and the majority of the data dates back to the late 19th and early 20th centuries. Much of the early work is based on collections made by Gloucester (Massachusetts) fishermen from the fishing banks of Atlantic Canada (Verrill 1864, 1878, 1922; Collins 1884; Goode 1887; Whiteaves 1901). These collections included specimens of *Paragorgia arborea*, *Acanthogorgia armata*, *Acanella arbuscula*, *Keratoisis ornata*, *Paramuricea grandis*, *Primnoa resedaeformis* and *Flabellum alabastrum*. Subsequently, Deichmann (1936) compiled and published the remainder of work by Verrill after he died in 1927 and included further descriptions of *P. arborea*, *A. armata*, *A. arbuscula* and *P. resedaeformis*. Miner (1950) provided brief descriptions of several species found in Atlantic Canada. Litvin and Rvachev (1963) described the bottom topography of Newfoundland and Labrador's fishing areas including the presence of "lime corals and their fragments" occupying several areas.

Hecker et al. (1980) conducted photographic surveys of three deep-sea canyons on the US side of Georges Bank and provided descriptions of several species of both scleractinians and gorgonians, many of which occur in Atlantic Canada. Tendal (1992) compiled and mapped existing data on the distribution of *P. arborea* including several locations around Atlantic Canada.

In the past decade, concern has been raised about the impacts of fishing activities on deep-sea corals off Atlantic Canada. Bottom trawling has been shown to have deleterious impacts on complex benthic habitats (Watling and Norse 1998; Auster and Langton 1999; ICES 2000). The structural characteristics and long-lived nature of deep-sea corals make them especially vulnerable to such impacts (Probert et al. 1997; Phillipart 1998; ICES 2000). Significant damage to deep-sea corals as a result of bottom trawling has been documented in several parts of the world including damage to *Solenosmilia variabilis* on seamounts off Tasmania (Koslow and Gowlett-Holmes 1998; Koslow et al. 2001), *Lophelia pertusa* reefs off Norway (Fosså et al. 2000) and *Primnoa* spp. off Alaska (Krieger 2001). In Nova Scotia, concerns first brought forward by fishermen (Jones and Willison 2001) were investigated by the Ecology Action Centre (EAC) and the results of a preliminary investigation are found in the report by Breeze et al. (1997) on the distribution and status of deep-sea corals off Nova Scotia. This report was the first comprehensive work that focused

on the distribution of deep-sea corals in Atlantic Canada, and more specifically it focused only on areas near Nova Scotia. The results are based on fishermen's Local Ecological Knowledge (LEK) as well as data from existing museum and scientific collections. The results show a general trend of deep-sea corals being distributed along the edge of the continental shelf at depths of 183-293 m and in deep canyons and channels at depths of 914-1097 m. The findings also confirmed the impressions of several fishermen, and in particular those who had been fishing for long periods of time, that there was a decrease in the abundance of corals in several areas off Nova Scotia where bottom trawling regularly occurred.

The First International Symposium on Deep-sea Corals (Willison et al. 2001) generated, in part, several new coral research and conservation initiatives being conducted by government, academic and non-government organizations. For example, preliminary results from recent investigations of coral habitats on the Scotian Shelf using underwater video found a total of 15 coral species ranging from the Northeast Channel to the northern Labrador Shelf with the highest densities observed at the mouth of the Northeast Channel and highest species diversity observed in the Gully and the Stone Fence (MacIsaac et al. 2001). World Wildlife Fund Canada produced a summary of the current state of knowledge of deep-sea corals in Atlantic Canada together with a review of their conservation objectives (Gass 2003). Mortensen et al. (2004) documented the effects of fishing in the Northeast Channel and 4 % of observed corals were impacted by fishing activities. The distribution of deep-sea corals in the Northeast Channel have been documented by Mortensen and Buhl-Mortensen (2004), and Mortensen and Buhl-Mortensen (2005) describe the distribution of corals in the Gully.

The goal of the present study was to better determine the distribution of deep-sea corals off Atlantic Canada by producing distribution maps based on three sources of information.

Local Ecological Knowledge

"Local Ecological Knowledge" (LEK) as used in this study can be described as knowledge gained by local residents about their environment based on experiences of living and/or working in the environment. This knowledge may have been gained by one person over a period of a few years, or accumulated by a community over several generations. Similar to many of the previous reports of deep-sea corals in Atlantic Canada, the present study relies partially on fishermen's LEK for information about the location and status of deep-sea corals in Atlantic Canada. Interviewing fishermen as a means of obtaining LEK for use in science and management has been practiced previously (Johannes 1981; Hutchings 1996; Breeze et al. 1997; Fuller and Cameron 1998; Neis and Felt 2000). Fishermen, as resource users, develop detailed knowledge of their resources, their environments, and their fishing practices, hence personal interviews with fishermen can elicit large amounts of information about species that are of both commercial and scientific interest (Neis et al. 1999). Some fishermen have fished the same grounds for decades, while some fishing

communities have existed for several hundred years (Neis and Felt 2000). In many cases, fishermen's knowledge of a fishery and the associated marine environments exceeds current scientific knowledge (Neis and Felt 2000). This is apparently the case with the current state of knowledge of the distribution of deep-sea corals in Atlantic Canada. Such continuous observation of one area over a long period of time, and wealth of data that it can yield, would be difficult to replicate given the financial and time constraints of many scientific research projects (Fischer 2000).

Methods

To identify as many locations of deep-sea corals as possible over the large spatial area of Atlantic Canada and within the two-year time frame of the study, three methods of data collection were used. Presence data for scleractinian and gorgonian corals were collected from the Canadian Department of Fisheries and Oceans (DFO) groundfish trawl surveys and from DFO fisheries observer records. These methods are described as *opportunistic* because corals are incidental catches during these activities. The third method of data collection involved interviewing fishermen in Novia Scotia and Newfoundland about their LEK of the distribution of deep-sea corals within their fishing grounds.

DFO groundfish trawl surveys

DFO conducts annual groundfish trawl surveys in the four regions of Atlantic Canada: the Maritimes, Gulf of St. Lawrence, Newfoundland and Labrador, and the Arctic. The general purpose of these surveys is to determine the distribution and abundance of economically important groundfish and shellfish species (DFO 1999), but corals are also incidentally caught during the surveys. All surveys used a stratified random sample design for selecting the trawl locations. Depending on the survey, different types of bottom trawls were used, including shrimp trawls and bottom trawls with and without rockhopper gear. The length of each trawl set was consistent for each survey, varying between 15 and 30 minutes. Specimens of corals were collected during surveys off Nova Scotia, Newfoundland and Labrador, and the Gulf of St. Lawrence between 1999 and 2001, and during the 2001 surveys in the Arctic. All corals caught during the cruises were labelled with the cruise and trawl sample numbers and kept frozen until they were identified.

Fisheries observer records

One of the primary objectives of the fisheries observer program is "to provide scientific data and management information for direct input into the management of Canada's fisheries and the conservation of fishery resources for the benefit of Canadians" (DFO 2001). This includes recording fishery bycatch. Fisheries observer coverage on vessels in Nova Scotia varies depending on the fishery, fishing grounds, gear type and vessel size. For example, foreign vessels and northern shrimp vessels have 100 % observer coverage, longline and bottom trawling vessels under 100 ft in length have a target of 5-10 % coverage, vessels over 100ft have a target of 10 % coverage, and small vessels using gillnets have less than 5 % coverage.

In 1999, coral species were added to the list of bycatch recorded by fisheries observers working on vessels fishing from Nova Scotia. To aid in this process, an identification guide for eight species of deep-sea corals found in Nova Scotian waters was provided to each observer. Observers recorded the species of corals found in the fishing gear and the location of the vessel at the time the specimens were retrieved.

Local Ecological Knowledge

Breeze et al. (1997) successfully interviewed 22 fishermen about their knowledge of coral locations off Nova Scotia. The fishing grounds included in the study ranged from Georges Bank to the Laurentian Channel. The majority of the participants lived in southern Nova Scotia. Two field sites were selected for the present study to supplement the initial interviews: Northern Nova Scotia (particularly Cape Breton Island) and Newfoundland.

Thirty-six interviews were conducted with fishermen in Nova Scotia and Newfoundland between July and November 2001. Participants were chosen using purposive sampling and snowball sampling. Purposive sampling involves choosing participants who are believed to yield the most comprehensive information and snowball sampling involves asking those participants to provide names of future participants (Babbie 1992). Further to the observation made by Maurstad (2000) that snowball sampling can create a bias by accessing participants with similar opinions and status, names of participants were also obtained from the Directory of Fishermen's and Other Organizations in Scotia-Fundy, the Fishermen and Scientist Research Society, and from professional contacts.

The selection of participants focused on vessel masters who had been fishing with bottom gears for at least 10 years (Mailhot 1994). This decision rule was made to obtain information on changes in the abundance of corals over time and therefore targeted fishermen who have been fishing over a long period of time.

The majority of the interviews took place in the fishermen's homes, but in several cases the interview took place on the wharf, and in one case on a fishing vessel. A semi-structured interview technique was used (Mailhot 1994). The interviews were not tape recorded, but rather the interviewers wrote down what was said. The interview started with several short answer questions regarding the fishing history and experience of the participants. For example, the number of years they had been fishing, whether they were captains or crew, and what type of fishing gear they used. These short answer questions were followed by questions about deep-sea corals to determine whether the participants were in fact familiar with these organisms. Next, the participants were asked about their fishing grounds, where they had caught corals, and with what gear type(s). Following this discussion, the appropriate nautical chart was chosen and the participant was asked to mark the locations of coral catches on the chart. To finish the interview the participants were asked about any changes they had observed in the locations and abundance of coral they caught throughout their careers.

Results

Groundfish trawl surveys

From 1999-2001, four research surveys on the Scotian Shelf, five off Newfoundland and Labrador and two in the Arctic region successfully retrieved 57 coral specimens among which seven species were identified. Figure 1 shows several examples of specimens caught during the surveys. Corals were caught at depths between 154 and 1400 m and were located from the Gulf of Maine to the Davis

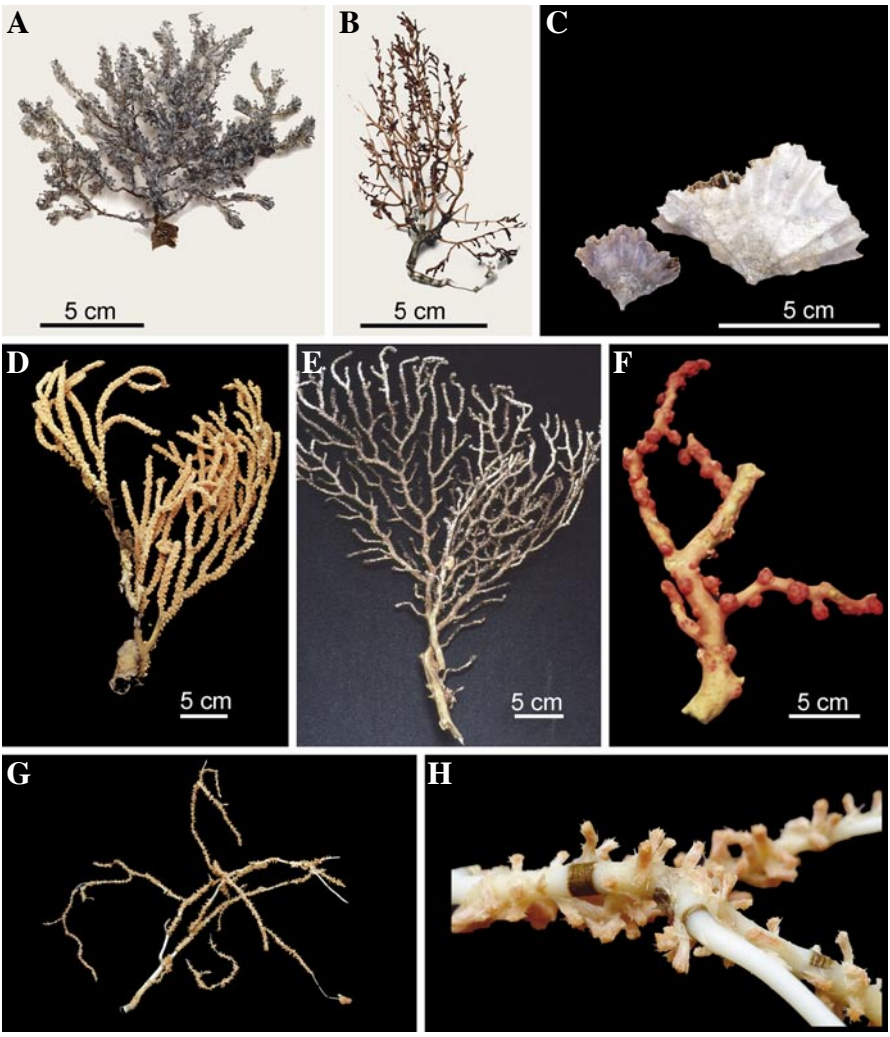

Fig. 1 Specimens collected from DFO groundfish trawl surveys 1999-2001. **A** *Acanthogorgia armata*; **B** *Acanella arbuscula*; **C** *Flabellum alabastrum;* **D** *Primnoa resedaeformis*; **E** *Paramuricea* spp.; **F** *Paragorgia arborea;* **G**, **H** *Keratoisis ornata;* Photos courtesy of Bio Photoshop

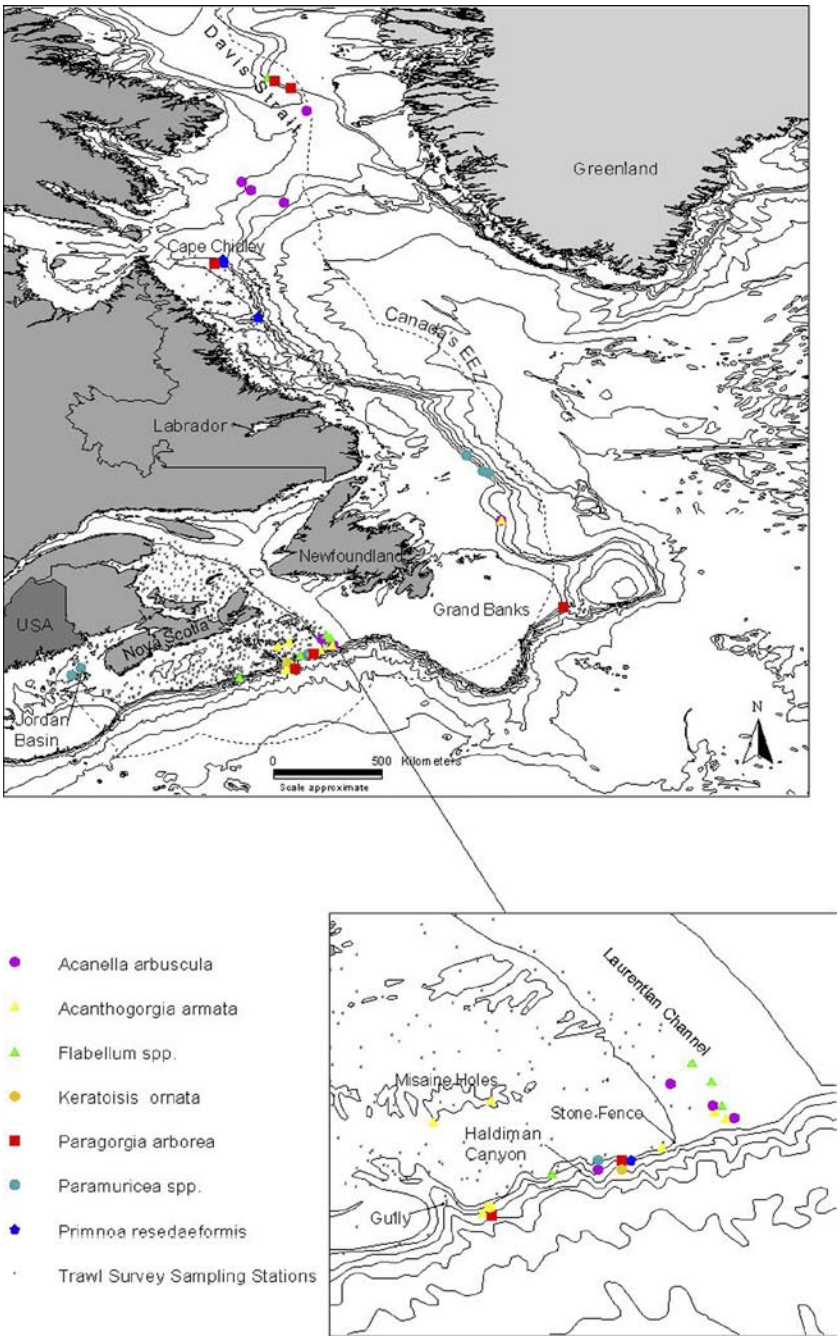

Fig. 2 The distribution of deep-sea corals off Atlantic Canada based on DFO groundfish trawl surveys from 1999-2001. Note: absence data was not available for three DFO southern Newfoundland and two Arctic surveys

Species	No. of records*	Locations **	Depth range at each location (m)	No. of occurrences with other coral species
Acanella arbuscula	4 – M	Haldiman Canyon (1T)	281	*Acanthogorgia armata* (3)
	1 – NF	Laurentian Channel (3T)	400-441	*Flabellum* spp. (2)
	5 – A	Davis Strait (T5)	468-1151	*Paragorgia arborea* (2)
	1 – FO (longline)	Newfoundland Slope (1T)	1400	*Paramuricea* spp. (1)
		Northeast Channel (1FO)	283	
Acanthogorgia armata	6 – M	Eastern Scotian Shelf (1T)	439	*Acanella arbuscula* (3)
	1 – NF	Stone Fence (T1)	380	*Flabellum* spp. (1)
		Laurentian Channel (2T)	400-419	*Keratoisis ornata* (1)
		Misaine Holes (2T)	164-201	*Paragorgia arborea* (1)
		Newfoundland Slope (1T)	1400	
Flabellum spp.	5 – M	Laurentian Channel (3T)	419-453	*Acanella arbuscula* (2)
	1 – A	Eastern Scotian Shelf (1FO; 2T)	278-510	*Acanthogorgia armata* (1)
	1 – FO (otter Trawl)	Davis Strait (1T)	516	*Paragorgia arborea* (1)
Keratoisis ornata	2 – M	Eastern Scotian Shelf (2T)	393-439	*Acanthogorgia armata* (1)
				Primnoa resedaeformis (1)
				Paragorgia arborea (2)
Paramuricea spp.	3 – M	Jordan Basin (2T)	154-222	*Acanella arbuscula* (1)
	3 – NF	Eastern Scotian Shelf (1T)	281	*Paragorgia arborea* (1)
	2 – FO (longline)	Newfoundland Slope (3T)	449-1159	*Primnoa resedaeformis* (1)
		Northeast Channel (2FO)	256-375	
Primnoa resedaeformis	1 – M	Jordan Basin (5FO)	166-229	*Paragorgia arborea* (20)
	3 – NF	Northeast Channel (82FO)	172-439	*Keratoisis ornata* (1)
	130 – FO (otter trawls, shrimp	Stone Fence (2FO)	307-333	*Lophelia pertusa* (1)
	trawls, longlines and gillnets)	Laurentian Channel (5FO)	411-467	*Paramuricea* spp. (1)
		St. Pierre Bank (1FO)	426	
		Cape Chidley (33FO, 2T)	324-463	
		Labrador Shelf (1FO, 1T)	280-379	
		Eastern Scotian Shelf (1T)	393	
Paragorgia arborea	2 – M	Northeast Channel (18FO)	249-439	*Primnoa resedaeformis* (20)
	2 – NF	SW Grand Banks (1FO)	720	*Keratoisis ornata* (2)
	2 – A	Labrador Shelf (2FO)	266-322	*Acanella arbuscula* (2)
	35 – FO (otter trawls, shrimp	Cape Chidley (13FO, 1T)	353-463	*Flabellum spp. (1)*
	trawls, longlines, gillnets)	Eastern Scotian Shelf (2T)	439-393	*Acanthogorgia armata* (1)
		NE Grand Banks (1T)	588	*Paramuricea* spp. (1)
		Davis Strait (2T)	516-556	
Lophelia pertusa	1 – FO (otter trawl)	Jordan Basin (1FO)	166	*Primnoa resedaeformis* (1)

Strait, generally along the edge of the continental shelf (Fig. 2; Table 1). The group of records lying on the Scotian Shelf east from the Gully to the Laurentian Channel denotes the highest coral species richness, with records for all seven species.

Fisheries observer reports

During 2000 and 2001, fisheries observers on board vessels fishing from Nova Scotia made 170 bycatch records of six species of corals caught by four different gear types (Table 1). Corals were caught at depths ranging from 166 to 720 m. Similar to the trawl survey results, these records indicate a general trend of deep-sea corals along the edge of the continental shelf off Nova Scotia and Newfoundland, as well as several records from Jordan Basin (Fig. 3). There are two major clusters of records: 1) the southwestern side of the Northeast Channel with 104 coral catches and 2) east of Cape Chidley, Labrador, with 46 coral catches.

Fishermen's Local Ecological Knowledge

Twenty-six successful interviews with fishermen contributed to the information collected for the locations of corals. Ten of the fishermen had not caught corals and are not considered further. Ten of the 26 interviews were conducted in Cape Breton, two on mainland Nova Scotia and 14 in Newfoundland. Twelve (six from Nova Scotia and six from Newfoundland) of the 26 participants were retired from fishing, and at least four fishermen recounted memories from as early as the late 1940s and early 1950s. Seventeen participants were captains of their fishing vessels, three previous captains had recently become managers and were no longer going out to sea, two were crew members, three had identified themselves as both captain and crew members depending on the fishing vessel, and the status of one participant was not identified.

Using photos and sample specimens, the fishermen identified eight species of deep-sea corals and the general locations where they were caught. Table 2 presents the species identified, the locations where they were caught, the years the fishermen fished those locations, and the number of participants who reported coral catches from those locations. Figure 4 presents the map of the coral species and general locations where fishermen reported catching corals. The larger gorgonian species were often referred to as *trees* and were not identified to the species level. Two fishermen presented me with specimens they had kept: one specimen of *L. pertusa* caught on the Stone Fence and one specimen of an Antipatharian coral retrieved from the continental slope off Newfoundland.

In general, the reports of corals from Newfoundland are more recent than those from Nova Scotia. The inshore cod fishery occupied most fishermen until the Atlantic cod moratorium in 1992. Post moratorium, fishermen in Newfoundland have been fishing for crab, shrimp and turbot in offshore areas at depths and locations more suitable for corals.

Table 1 The coral fauna

* Maritimes Trawl Surveys (M); Newfoundland Trawl Surveys (NF); Arctic Trawl Surveys (A); Fisheries Observer (FO)

** T = Record from a Trawl Survey; FO = Record from a Fisheries Observer

Commonalities among the three sources of data

The three sources of data (i.e. the fisheries observer records, the DFO groundfish trawl surveys and LEK) provided data on the distribution of corals in Atlantic Canada. Further, the three sources provided both unique as well as overlapping data. The complete data set from all three sources is plotted in Figure 5.

The DFO fisheries observer records and trawl surveys both revealed corals found in Jordan Basin, but different species were recorded. None of the fishermen interviewed fished as far west as Jordan Basin and the Northeast Channel, thus

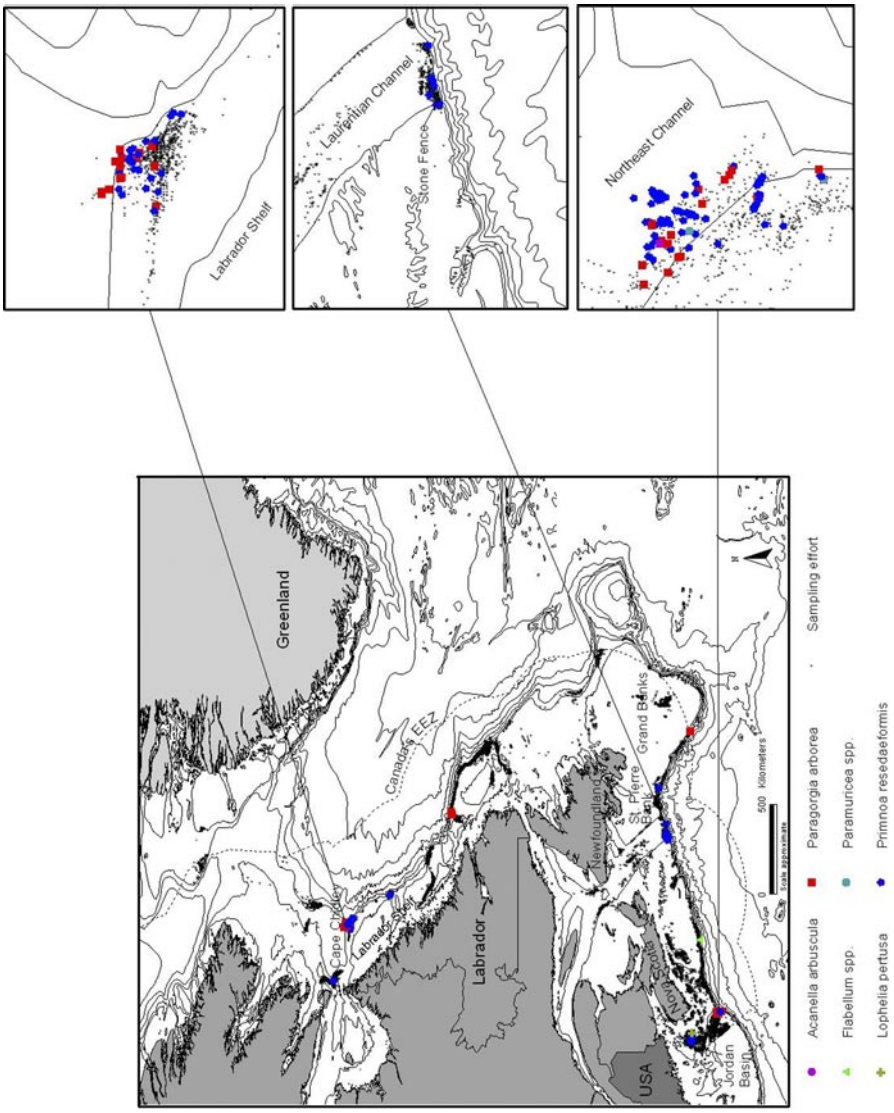

Fig. 3 The distribution of deep-sea corals based on fisheries observer records for 2000-2001

Table 2 Results from fishermen's LEK

Species	Location	Years fished	No. of participant(s)
Acanella arbuscula	Edges of holes on Misaine Bank	1965-1990	1
	Continental Shelf and Slope off Nfld. & Labrador	1976-2001	3
	Funk Islands	1992-2001	1
Keratoisis ornata	Stone Fence	1948-1974	1
	Gulf of Saint Lawrence	1984-1985	1
	North of Grand Banks at EEZ	1992-2001	1
Paragorgia arborea	Emerald Basin		1
	Edge of holes on Misaine Bank	1965-1990	1
	Stone Fence	1948-2001	4
	Gully	1969-2001	2
	Southern Edge of Banquereau Bank	1980-2001	1
	Edge of St. Pierre Bank	1980-2001	1
	North of Grand Banks at EEZ	1952-2001	1
	Continental edge & slope off Nfld.	1987-2001	3
	Funk Islands	1970-1990	1
Paramuricea spp.	On Banks off Cape Breton	1974-1998	1
	Edges of holes on Misaine Bank	1965-1998	2
	Tail of the Bank	1992-2001	1
	North of Grand Banks at EEZ	1992-2001	1
	Continental shelf edge and slope off Nfld.	1992-2001	2
Primnoa resedaeformis	St Ann's Bank	1975-1995	1
	Edges of holes on Misaine Bank	1965-1990	1
	Gully	1948-2001	3
	Stone Fence	1948-2001	3
	Southern edge of Banquereau Bank	1980-2001	1
	Edge of St Pierre Bank	1980-2001	1
	North of Grand Banks at EEZ	1992-2001	1
	Funk Islands	1992-2001	1
	Continental Shelf Slope off Nfld.	1992-2001	1
	Off Cape Spear	1986-2001	1
	North of Labrador	1998	1
Trees	Stone Fence	1934-1992	4
	Edge of Laurentian Channel	1962-1992	1
	Gully	1934-1993	3
	Southern edge of St. Pierre Bank Southeast edge of Grand Banks at EEZ North of Grand Banks at EEZ North edge of shelf	1992-2001	1
Flabellum spp.	Middle of the Scotian Shelf Most westerly location seen on map	1980-present	1
Lophelia pertusa	Edges of holes on Misaine Bank	1965-1990	1
	Stone Fence	1934-2001	3
	Gully	1934-1980	1
Antipatharian	Continental Slope off Nfld	2000-2001	1

the DFO provided a complementary data source. The Northeast Channel was not sampled by the DFO trawl surveys and therefore fisheries observer records were the only source of data for this location.

Further northeast along the edge of the Scotian Shelf, there were two reports of *Flabellum* spp., one from a fisherman and one from a fisheries observer record. Reports of corals in the Gully only came from fishermen. There were five trawl survey stations in this area and five fisheries observer records in this area, none of which reported coral catches. Reports of corals in and around the holes in the

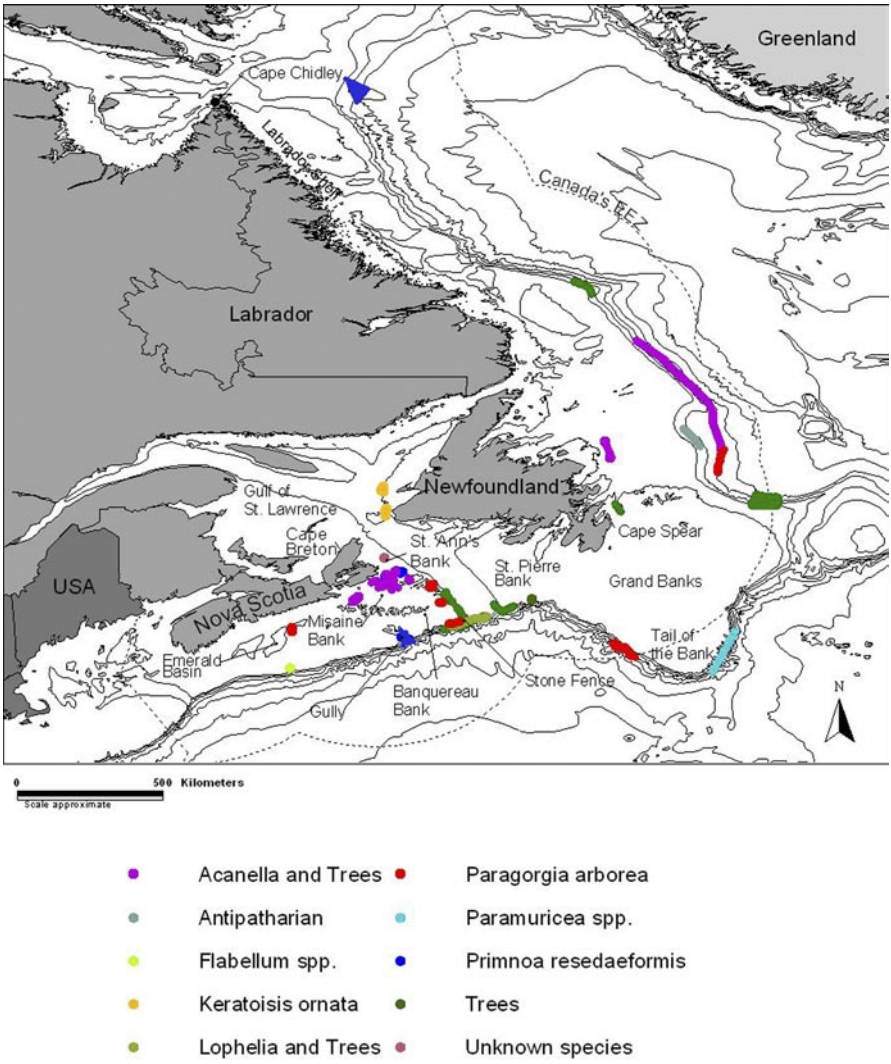

Fig. 4 The distribution of deep-sea corals as identified by fishermen's local ecological knowledge. Note: in several cases large gorgonian species were referred to as *trees* and were not identified to the species level

inshore areas off Cape Breton primarily came from fishermen. The exception was further offshore, with two reports from trawl surveys of *A. armata* in and on the edges of the Misaine Holes.

All three sources of data identified coral locations on the Stone Fence. Both fisheries observers and fishermen's reports indicated that corals are present on the southern edge of St. Pierre Bank. The fisheries observers reported *P. resedaeformis* and the fishermen reported *trees*. Fisheries observer records and fishermen's reports on the southwest side of the Grand Banks just inside the 200-mile EEZ overlapped, with both sources reporting the presence of *P. arborea*.

Changes in coral abundances observed by fishermen

Seven fishermen said that they had noticed changes in the abundance of deep-sea corals over time. Three fishermen reported decreases in the number of corals seen on the eastern Scotian Shelf. One participant fished from 1970-1990 and commented that in the early 1980s he did not see the large corals that he saw in the 1970s. In particular, he reported that the Stone Fence is now "as level as a table", and "is a desert compared to what it used to be". He attributed these changes to the impacts of bottom trawlers. Another participant also commented on seeing changes on the Stone Fence over a 10-year period starting in 1958. The first six years he fished the Stone Fence, he stated he could fill his dory (a small rowing boat) with corals caught on his fishing lines. By the 10th year of fishing on the Stone Fence he reported that the corals were gone. He attributed the disappearance of corals to the large trawlers that began fishing in the area for redfish and cod in 1964. Another fisherman also commented that from the 1950s to mid 1970s, he noticed a decrease in the number of corals he saw on the Stone Fence and also attributed the changes to the impact of bottom trawling in the area. However, a fisherman who still longlines on the Stone Fence stated that he saw fairly large pieces of coral on the Stone Fence in 2000, indicating there are some existing coral colonies or coral aggregations.

Two fishermen, one who has fished in deep-water since 1987 and another who has been fishing in deep-water since 1992, remarked that they had not seen any changes in the abundance of corals on the continental slope off Newfoundland. Such statements suggest that there may have been lower impacts of fishing in this area during this time period.

Discussion

Using three sources of information, the fishermen's LEK, fisheries observer records, and DFO groundfish trawl surveys, proved to be an effective way to gather data on the location of deep-sea corals. In several cases, coral locations from different sources of data overlapped, enhancing confidence in the reliability of each method. Each method also provided unique locations thereby expanding the results beyond what would have been found by the use of only one or two of these methods. Fishermen were able to identify species and their locations and demonstrated that LEK is valuable and provides historical data largely unavailable from any other source. Cumulatively, the fishermen provided data from a large spatial area.

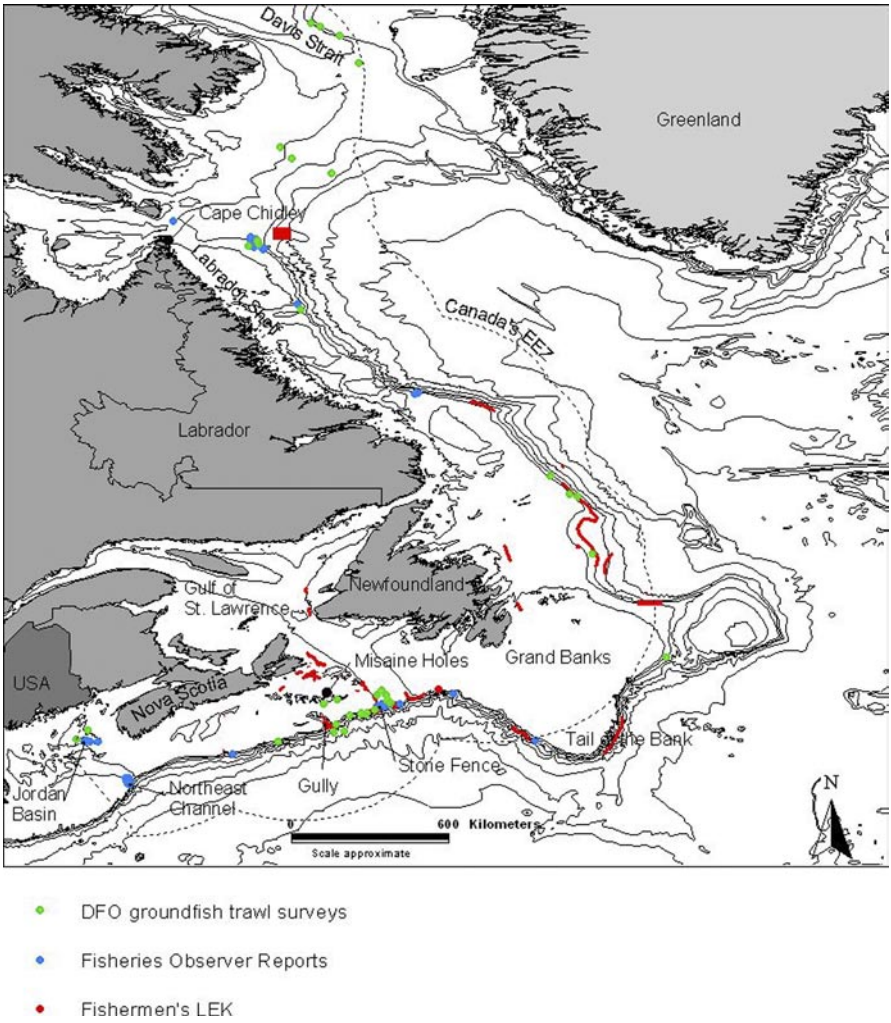

Fig. 5 The distribution of deep-sea corals off Atlantic Canada based on data collected from DFO groundfish trawl surveys, fisheries observer records and fishermen's local ecological knowledge

Locations identified by fishermen, especially those that were identified by more than one participant, can be made available to scientists to assist in planning surveys of deep-sea corals using remotely operated vehicles or submersibles.

The results from this study confirm and add to the existing knowledge about the distribution of deep-sea corals in Atlantic Canada. The distribution of six species of gorgonians and two scleractinian species were further clarified from previous reports (Breeze et al. 1997; Mukhida and Gass 2001). *Paramuricea placomus* and *Paramuricea grandis* are difficult to differentiate and hence were not identified to

the species level. Furthermore, it is difficult for fishermen and fisheries observers to distinguish between the three species of *Flabellum* (*F. alabastrum, F. macandrewi, and F. angulare*). Only *F. alabastrum* was included in the identification guide, creating an obvious bias for this identification. In addition to these species, Breeze et al. (1997) confirmed the presence of *Anthothelia grandiflora*, *Radicipes gracilis* and *Javania cailleti*. It is possible that these species were not confirmed here because they were not included on the identification guide. However, a new species to Atlantic Canada, thought to be *Bathypathes arctica* from the order Antipatharia, was discovered.

The known range of several species was expanded particularly in the case of species identified offshore of Newfoundland and Labrador. New locations were identified for the reef building coral *L. pertusa*. This species is likely rare in Atlantic Canadian waters as this area represents its northern limit in the Northwest Atlantic (Zibrowius 1980).

Areas of special interest off Nova Scotia

Several areas of special interest near Nova Scotia were identified in the study with respect to coral abundance and/or diversity.

Jordan Basin

Jordan Basin was not included in the coral distribution study by Breeze et al. (1997). Tendal (1992) presented records of *P. arborea* from this region and Verrill (1878) presented records of *P. resedaeformis* from the mouth of the Bay of Fundy. Furthermore, records of *P. resedaeformis* and *Paramuricea* spp. from this area have recently been confirmed by researchers at the University of Maine (Watling, unpublished observation). Corals in this area were found at relatively shallow depths for these species. Although *L. pertusa* has been reported to occur off Nova Scotia (Hecker et al. 1980; Zibrowius 1980; Breeze et al. 1997), very few records exist which include specific locations. Therefore the report of a specimen caught in Jordan Basin is valuable and provides more detail about the occurrence of this species.

Northeast Channel

Several maps based on fishermen's LEK highlight the Northeast Channel as an area with particularly high coral abundance (Goode 1887; Breeze et al. 1997; Willison et al. 2002). Data collected by the fisheries observers indicate high concentrations of *P. resedaeformis* and *P. arborea* on the Georges Bank side of the Northeast Channel. In 2000 and 2001, the Northeast Channel was surveyed using a towed camera system that confirmed a high abundance of corals (MacIsaac et al. 2001; Mortensen and Buhl-Mortensen 2004).

Eastern Scotian Shelf

The present study demonstrates that the region along the edge of the continental shelf between the Laurentian Channel and the Gully has relatively high coral species richness. There were records for all gorgonians and scleractinians reported in the

current study, including fishermen's reports of *L. pertusa* in the Gully and along the edge of continental shelf near the Stone Fence. This area also contains the two records of *K. ornata* reported from the DFO groundfish trawl surveys. The small number of reports of *K. ornata* suggests that it may be relatively rare compared to the other coral species identified in this study. Collins (1884) recalled catching the greatest concentration of it along the middle prong on the edge of Banquereau Bank, which is in the centre of this region. The Gully was also identified as a significant coral area by a number of longline fishermen, however, no reports came from the other sources. This could be attributed to a patchy distribution of corals which may exist in the Gully and because the steep nature of the canyon makes it unfavorable for trawling.

Gulf of Saint Lawrence

The report of *K. ornata* from the Gulf of St. Lawrence not only extends the known range of *K. ornata* beyond the Scotian Shelf as described by Collins (1884), Verrill (1878), Verrill (1883), Deichmann (1936), Miner (1950), and Breeze et al. (1997), but also represents the first record of corals from the Gulf of St. Lawrence region. *K. ornata* is also a species of interest because it has only been reported from Atlantic Canada and therefore may be an endemic species.

Stone Fence

Breeze et al. (1997) identified the Gully and the Northeast Channel as two main hotspots of coral abundance near Nova Scotia. The present study confirms a high abundance of corals in the Gully based on reports from fishermen. However, several fishermen, who fished both the Gully and Stone Fence, identified the Stone Fence as hosting the largest specimens and the greatest abundance of corals. Furthermore, there were four reports of *L. pertusa*, a relatively rare species, from the area**.** Several *L. pertusa* reefs concentrated in one area on the Stone Fence have recently been precisely located (see below). Collins (1884) referred to the region of the Stone Fence as the place of greatest abundance of *P. resedaeformis* and Goode (1887 Explanation of Chart No. 4, XVII) remarked that the Stone Fence "is noted for the great abundance of corals growing on the bottom". Finally, Litvin and Rvachev (1963) also depict corals present on the Stone Fence in their description of bottom deposits in the region.

Newfoundland and Labrador

There are few previous references to corals off Newfoundland and Labrador. Therefore, the records presented here have greatly increased existing knowledge of the distribution of corals in this region. Litvin and Rvachev (1963) described five occurrences of corals in their description of the sediment deposits on the Grand Banks and on the shelf and slope of northern Newfoundland and Labrador. Tendal (1992) described two records of *P. arborea* on the slope of the Grand Banks. The present study identified six gorgonian, one scleractinian, and one antipatharian species off Newfoundland and Labrador. All of these species were also found off Nova Scotia, except for the antipatharian that has not been previously recorded in Atlantic Canada.

Corals from the order Antipatharia are commonly known as the black or thorny corals and are typically organisms found in deeper and abyssal ocean waters (Hyman 1940). They are rare in the Northwest Atlantic north of the southern US (Kramp 1932). The specimen reported here was collected from the continental slope at a depth between 800 and 1000 m. It is likely that this specimen is *Bathypathes arctica* as it is the only species of antipatharian reported this far north in the western Atlantic. The species was first described as *Antipathes arctica* by Lütken in 1871, when it was taken from the stomach of a shark captured off the coast of northern Greenland (Brook 1889). It was later removed from the genus *Antipathes* and referred to *Bathypathes* by Pax in 1932. It has since been reported west of Greenland at depths of 1100-1200 m (Kramp 1932; Pax 1932) and northeast of the Faroe Islands (Pax 1932).

The data presented in this study overlap with several earlier reports of Newfoundland corals. Litvin and Rvachev (1963) reported corals on the northeast side of the Grand Banks, which is at a shallower depth but similar latitude to a DFO groundfish trawl survey record. In addition, their locations of corals off northern Newfoundland overlap with reports from fishermen and DFO groundfish trawl surveys. One discrepancy with previous coral distributions lies with Tendal (1992) who equates the lack of *P. arborea* off the Labrador coast to the low temperatures found in these areas (he reports temperatures of 3.0-3.5˚C). Regardless of the cool temperatures, which were recorded during the DFO groundfish trawl surveys to be between 3.4-4.4˚C, all three sources of information in the current study provide data for corals, including *P. arborea*, off the Labrador coast.

The depths and location records for *A. arbuscula* from the present study are consistent with previous reports. Miner (1950) described *A. arbuscula* as abundantly distributed in deep-water on the banks off Nova Scotia and Newfoundland. Opresko (1980) also described *A. arbuscula* to occur as far north as Newfoundland. The present study, and especially the information provided by Newfoundland fishermen, confirms this information. It would appear however, based on information collected from the interviews, that *A. arbuscula* is more common off Newfoundland than other coral species. In one instance, roughly a hundred specimens of *A. arbuscula* were seen scattered on a wharf and tangled in a gillnet in a fishing village in Newfoundland. Specimens of *A. arbuscula* collected from this wharf were shown during the following interviews and this may have increased the probability of fishermen reporting it. Moreover, it is possible that *A. arbuscula* is more easily caught by gillnets compared with other species. *A. arbuscula* is one of the few species that does not require hard substrate on which to attach but rather has a root-like structure that is used as a support in soft sediments (Opresko 1980). This may make it more susceptible to being taken in gillnets compared with other species which are more firmly attached to hard substrate such as rocks and boulders.

The data presented here for *Paramuricea* spp. off northern Newfoundland extend its range beyond previous records from off New England, Nova Scotia and on the Grand Banks (Verrill 1883; Deichmann 1936; Miner 1950; Opresko 1980; Breeze et al. 1997).

Conservation concerns and actions

The results from the interviews, in addition to the past reports made by Goode (1887), Whiteaves (1901), Verrill (1922), and Breeze et al. (1997), reveal that fishermen working off Nova Scotia have been catching corals throughout the late 19th and 20th centuries and continue to catch them today. The fisheries observer records and the interviews with fishermen point to three gear types that catch corals: bottom trawls for groundfish and shrimp, bottom longlines, and set gillnets. Results from the interviews with fishermen in Nova Scotia report significant change to bottom habitats on the eastern Scotian Shelf, and in particular the disappearance of hard bottom and decreases in the size and number of the corals on the Stone Fence. They attribute these changes to damage caused by mobile bottom trawls. Although fishermen attribute the major changes to mobile bottom trawls, fishermen fishing with fixed gear also reported coral catches. The proportion of damage caused by mobile *versus* fixed gear remains unclear. The extent of damage to corals as a result of fixed gears has been documented in the Northeast Channel where 4 % of colonies where damaged; there was no evidence that trawling occurred in the area (Mortensen et al. 2004). However, trawling is a mobile fishing gear which covers a greater surface area of the seabed and is accompanied by a greater force resulting in more destructive potential when it comes into contact with the seabed and corals. Also, there is some incentive for fixed gear fishermen to avoid coral areas because their gear can be snagged. As in all cases, the degree of impact will depend on the level of fishing effort in coral areas.

The majority of references to corals on the Stone Fence are based on data collected prior to 1965 (Collins 1884; Goode 1887; Litvin and Rvachev 1963; Breeze et al. 1997). In addition, reports made by fishermen reported here refer to catches made prior to 1992, in several cases prior to 1980, and in one case prior to 1970. Therefore, the present state of coral communities on the Stone Fence remains unclear. There was, however, one fisherman who continues to longline in this area and who reported catching pieces of *P. resedaeformis* in 2000. Furthermore, fisheries observers report several catches of *P. resedaeformis* from the Stone Fence, and the DFO groundfish trawl surveys caught a specimen of *A. armata* in the area. A DFO survey in 2002 using a towed camera has confirmed the presence of one piece of live *L. pertusa* among *Lophelia* rubble on the Stone Fence (personal observation; Auld 2002). A second DFO survey in 2003 returned to the same area and found a one kilometre by 500 m area of *L. pertusa* reefs, 99 percent of which was described as rubble and appeared to have been damaged by bottom trawlers (Mortensen pers. comm. 2003; Sayfy et al. 2003). Although there are indications that corals still exist on the Stone Fence, there does not appear to be the outstanding abundances that were reported at the end of the 19th century and first half of the 20th century. As a result of the recent findings and efforts by local non-government environmental organization, consultations are currently underway regarding the design of a closed area to protect the *L. pertusa* reefs.

Interviews with fishermen in Newfoundland suggest that corals were not caught in the Atlantic cod fishery, which was the major fishery off Newfoundland prior to

the cod fishing moratorium in 1992. Since 1992, Newfoundland fishermen focused more of their fishing efforts on shrimp, snow crab, and offshore groundfish such turbot. It appears that fishermen in the deep-water turbot fishery on the continental slope off Newfoundland are catching corals. The turbot fishermen, however, have not noticed a change in bottom type or coral abundance over the past ten years. This may not reflect the actual situation as it could take some time before coral abundance falls noticeably, by which time the impact may likely be considerable.

The discovery of a specimen of an antipatharian coral, an order not yet recorded in Atlantic Canada and caught in deep-water (800-1200 m), is an indication of how little is known about benthic communities beyond the continental shelf. Therefore, although the fishermen have not noticed a change in the abundance of corals off Newfoundland, caution should be applied when carrying out potentially harmful activities in unfamiliar environments.

The fisheries observer data reveal two areas that have experienced relatively high coral catches in the past two years in Atlantic Canada. These are the Northeast Channel off southwest Nova Scotia and the region east of Cape Chidley, Labrador. In both cases, the majority of the records are of *P. resedaeformis* and to a lesser extent *P. arborea*. The coral catches reported from the Northeast Channel were caught using longline, bottom trawls and gillnets, and therefore the data are derived from only 5-10 % of the total catches from that area assuming that the fisheries observer program reached its observer coverage targets. This contrasts with the reports from the Northern Shrimp fishery east of Cape Chidley which has 100 % observer coverage.

The Northeast Channel has been attracting much attention over the past two years based on the efforts of fishermen (see Willison et al. 2002), earlier reports of corals by Breeze et al. (1997), and the results of two consecutive years of DFO and Dalhousie University surveys of the coral communities in this region (Mortensen and Buhl-Mortensen 2004). As a result of these surveys, and the increased public awareness of the need to protect deep-sea corals in Nova Scotia, a Coral Conservation Area fishery closure was established in the Northeast Channel in 2002 (DFO 2002).

Unlike the Northeast Channel, the region showing high coral catches off Labrador has had no consideration regarding protecting the corals in the area. Fisheries observers started recording coral bycatch data in 2000. Therefore, we do not know the extent of damage prior to this time. This region merits further exploration using video and photographic surveys to assess the status of the coral communities in this region.

The Gully has been identified as an Area of Interest (AOI) under Canada's Oceans Act. The AOI is currently undergoing the process to be designated a permanent marine protected area. The Gully initially attracted attention because it is home to an endangered population of the Northern Bottlenose Whales, however, subsequent information came to light that the Gully also provides habitat for deep-sea corals and is an area of relatively high coral species richness on the Scotian Shelf (Breeze et al. 1997; MacIsaac et al. 2001).

Recent efforts to protect known hotspots of deep-sea corals off Nova Scotia are positive steps towards the long term survival of this group of species, however, the

full extent of damage to coral populations as a result of fishing activities off Atlantic Canada remains unknown. A suggestion for future research is to use predictive models to gain insight into suitable habitats for corals off Atlantic Canada and to overlay this distribution with past and present fishing effort (i.e. longlines, gillnets and bottom trawls). This may elucidate the potential extent of damage which has occurred over the past century and the areas which remain under threat. This will ultimately assist to focus conservation efforts in areas where they will be most effective.

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