DETERMINING DEEP-SEA CORAL DISTRIBUTIONS IN THE NORTHERN GULF OF ST. LAWRENCE USING BYCATCH RECORDS AND LOCAL ECOLOGICAL KNOWLEDGE (LEK)

by

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ABSTRACT

Deep-sea corals have recently received attention due to an increased awareness of their diversity and vulnerability to commercial fisheries. Over 50 species of coral have been identified in Atlantic Canada and the distribution of these species is now fairly well known. However, the deep-sea corals in the Northern Gulf of St. Lawrence have not been previously studied. This study used DFO groundfish survey trawl and fisheries observer records of coral bycatch along with the local ecological knowledge (LEK) of fish harvesters to identify 11 species/groups of deep-sea coral that occur in the Northern Gulf of St. Lawrence (4RSPn) and to map the distribution of seven of these species/groups. Nephtheid soft corals and sea pens (Pennatulacea) are the most common groups occurring in the Northern Gulf. Fish harvester observations on deep-sea coral distributions and coral bycatch in Northern Gulf fisheries are reported along with their opinions on the impacts of different gear types and on protecting corals in the Northern Gulf. Fish harvesters reported that coral bycatch was observed when fishing for eight different target species while using six different gear types and most reported observing a relationship between sea pens and commercial fish species in the Northern Gulf including Atlantic cod (*Gadus morhua*), Atlantic halibut (*Hippoglossus hippoglossus*), Greenland halibut/turbot (*Reinhardtius hippoglossoides*) and Northern shrimp (*Pandalus borealis*). Fish harvesters' LEK identified a greater diversity corals than the other two sources of data used, which is likely due to fishing in a wider range of habitats than survey trawls and the longer time periods of observation accessed through fish harvesters' LEK. There were advantages to using multiple sources of data given the current gaps in our knowledge of deep-sea corals in the Northern Gulf. Each source of data had its own limitations, which are discussed in this thesis, but when used together it was possible to determine deep-sea distribution patterns in the Northern Gulf and to gain insight into the occurrence of deep-sea coral bycatch in Northern Gulf fisheries.

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LIST OF ABBREVIATIONS & SYMBOLS

ASH- Aragonite Saturation Horizon

CURRA- Community-University Research for Recovery Alliance

$CaCO_3$- Calcium Carbonate

DFO- Fisheries & Oceans Canada

EEZ- Exclusive Economic Zone

FFAW- Fish Food & Allied workers

FOP- Fisheries Observer Program

FOR- Fisheries Observer Records

ICEHR- Interdisciplinary Committee on Ethics in Human Research

LEK- Local ecological knowledge

MPA- Marine Protected Area

NAFO- Northwest Atlantic Fisheries Organization

NGO- Non-Governmental Organization

POM- Particulate Organic Matter

ROV- Remotely-operated vehicle

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CHAPTER ONE: INTRODUCTION

1.1 INTRODUCTION

Deep-sea corals are invertebrates in the class Cnidaria that have skeletons composed of calcite, aragonite and protein. Some corals, such as Alcyonacean soft corals lack a true skeleton but still have calcite in hardened spicules called sclerites. There are over 3000 species of deep-sea coral globally (Cairns 2007) and about 60 species in Atlantic Canada (Wareham 2009). Deep-sea corals form habitat for other species of invertebrates and fishes (Buhl-Mortensen & Mortensen 2005, Buhl-Mortensen et al. 2010). Deep-sea corals have been documented in the scientific literature since the mid-eighteenth century yet it is only in the past 40 years that we have had the technology necessary to reveal the true extent of the global distribution of deep-sea corals (Roberts et al. 2009). Technology has allowed us to explore new, deeper sections of the ocean floor, but similar and concurring technology in the fishing industry has opened the world's coastal inshore areas, continental shelves and margins to bottom fishing. Bottom fishing refers to fishing using any gear type that may come into contact with the seafloor (Chuenpagdee et al. 2003, Fuller et al. 2008) and deep-sea corals are particularly vulnerable to bottom fishing due to their slow growth rates and longevity (Roberts et al. 2006).

Deep-sea corals are important species that add to the biodiversity of the oceans as species themselves but also have been shown to play an important role in benthic ecosystems. Deep-sea habitats that contain deep-sea corals are emerging as systems of ecological (e.g. Krieger & Wing 2002, Buhl-Mortensen and Mortensen 2005) and economic importance (e.g. Foley et al. 2010), raising concern over their rapid destruction (Watling et al. 1998, Fosså et al. 2002, Roberts et al. 2009). The economic importance of deep-sea corals is the habitat that they provide for commercial species of invertebrates and fish (Baillon et al. 2012). The distribution, abundance and diversity of deep-sea corals is now fairly well known for Atlantic Canada as a whole, but there has not been much focus on deep-sea corals found in the Northern Gulf of St. Lawrence, encompassing NAFO (Northwest Atlantic Fisheries Organization) divisions 4R, 4S and 3Pn (see Figure 1.1).

This study was part of the CURRA (Community-University Research for Recovery Alliance) at Memorial University in St. John’s, Newfoundland and Labrador. The CURRA was an initiative whose main goal was to help communities on the west coast of Newfoundland to develop strategies for the recovery of fish stocks and fishing communities. Another goal of the CURRA was to directly involve fish harvesters and fishing communities in a series of interdisciplinary research projects where methods from both the natural and social sciences were used to answer biological and management questions.

One of the components of the CURRA was to link scientific research and the local ecological knowledge (LEK) of fish harvesters to assess biogenic habitats in the Northern Gulf of St. Lawrence that may provide fish habitat, including deep-sea corals. The main purpose of this study was to determine the distribution, abundance and species richness of deep-sea corals in the Northern Gulf of St. Lawrence using three different sources of information. These included (1) coral bycatch records from DFO (Fisheries & Oceans Canada) research survey trawls, (2) fisheries observer records of deep-sea coral bycatch and, (3) knowledge obtained through interviews with Northern Gulf of St. Lawrence fish harvesters. Further, during these interviews, fish harvesters from multiple gear sectors (gillnetters, longliners and shrimp trawlers) were asked questions on their first-hand observations of deep-sea coral bycatch in Northern Gulf fisheries, changes in the amount of coral bycatch observed over time and the relationship between deep-sea corals and fish in the Northern Gulf of St. Lawrence. Questions on their opinions of the target fisheries and gear types that produce the most coral bycatch and appropriate measures for protecting corals in the Northern Gulf were also recorded.

Chapter One introduces the thesis, locates it in the larger literature and provides an overview of the different chapters. The biology and ecology of deep-sea corals, the habitats they provide and threats to deep-sea corals are discussed. Chapter One also provides an introduction to research on commercial fish harvesters' local ecological knowledge (LEK) and its practical uses when included in science and management. Finally, Chapter One provides an introduction to the Northern Gulf of St. Lawrence ecosystem and its commercial fishing industry.

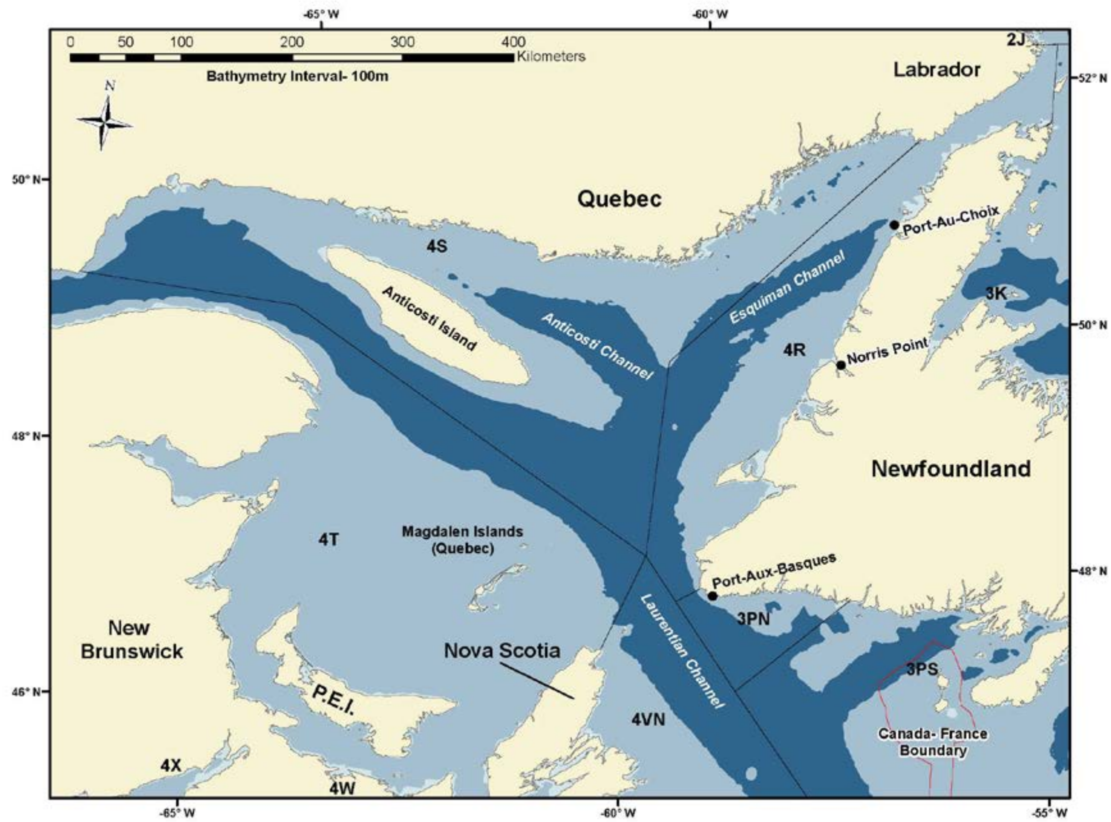

Figure 1.1: The Northern Gulf of St. Lawrence (encompassing NAFO divisions 4R, 4S and 3Pn)

1.2 BIOLOGY & ECOLOGY OF DEEP-SEA CORALS

While deep-sea corals have been known to occur for several centuries, it is only in the last ten to twenty years that there has been serious research undertaken on the biology of the corals themselves and the ecology of the habitats they provide (Roberts et al. 2009). Technological advancements such as submersibles, remotely operated vehicles (ROVs), long-term monitoring platforms and seafloor observatories are allowing such investigations. ROVs can take high definition photographs and video, collect samples and set up experiments on the seafloor and thus are used to explore the behaviour, physiology, reproduction, growth rates and larval settlement of deep-sea corals.

The slow growth rates and longevity of deep-sea corals make them particular vulnerable to disturbance (Roberts et al. 2006). For example, the reef-forming Scleractinian *Lophelia pertusa* can be thousands of years old (Hall-Spencer et al. 2002). Large gorgonians, such as *Keratoisis grayi* and *Primnoa resedaeformis*, which are found on the continental slopes of Atlantic Canada, can grow to be hundreds of years old (Sherwood & Edinger 2009). Estimates from growth models indicate that the Scleractinian cup coral, *Flabellum alabastratum*, can grow to at least 45 years of age (Hamel et al. 2010). Less is known about the growth rates and longevity of Alcyonacean soft corals such as *Gersemia rubiformis* and *Anthomastus grandiflora* (Sun et al. 2011) and sea pens (Langton et al. 1990, Wilson et al. 2002, Neves et al. 2013a, Neves et al. 2013b, Neves et al. 2015). While Antipatharians (black corals) have been found to have variable growth rates (Carreiro-Silva et al. 2013), some species can live for millennia (Houlbreque et al. 2010, Prouty et al. 2011)

Below is a review of research findings on deep-sea coral taxonomy, feeding and reproductive behaviours, environmental controls on distribution and the local and global distribution of deep-sea corals.

1.2.1 Taxonomy

Deep-sea corals are marine invertebrates from the phylum Cnidaria. Cnidarians are biradially symmetrical marine invertebrates characterized by possessing stinging cells called cnidocytes which are used in both prey capture and predator defense (Roberts et al. 2009). Corals are cnidarians with skeletons and can be either solitary or colonial. Coral colonies are made up of many polyps, with each polyp possessing a central mouth surrounded by a ring of tentacles (Roberts et al. 2009). Most deep-sea corals are in the class Anthozoa, like their tropical, shallow-water counterparts. The main difference between deep-sea and shallow-water corals is the lack of symbiotic algae called zooxanthellae in deep-sea species. The deep-sea corals found in Atlantic Canada are mostly octocorals and are non-reef forming, ahermatypic corals. The Scleractinian *Lophelia pertusa* is the only reef-forming coral found in Atlantic Canada (Cogswell et al. 2009).

Groups and species of deep-sea coral can be distinguished based on characteristics of their mesenteries, tentacles and skeletons. All deep-sea corals require calcium carbonate ($CaCO_{3)}$ to form their sclerites and carbonate skeletons. They obtain this from Ca^{2+} and CO_3^{-2} ions found in seawater. While the relative importance of both calcite and aragonite may vary among taxa, all corals require $CaCO_3$ for their structural development (Bayer & Macintyre 2001).

There are two subclasses of deep-sea corals; Hexacorallia and Octocorallia. Octocorals include Alcyonacean soft corals (i.e. *Gersemia rubiformis* and *Anthomastus grandiflorus*), sea pens (e.g. *Pennatula aculeata*, *Halipteris finmarchica*, *Umbellula lindahli*) and gorgonians such as *Acanthogorgia armata*, *Keratoisis grayi* and *Primnoa resedaeformis*. Octocoral polyps have eight tentacles and unpaired mesenteries. All octocorals contain calcium carbonate ($CaCO_3$) sclerites in their polyps, and their skeletons range from soft corals without rigid skeletons to those with flexible internal skeletons made from protein, gorgonin, or a more solid calcite skeleton (Roberts et al. 2009).

Within the subclass Hexacorallia, there are two orders; Scleractinia and Antipatharia. Scleractinians include hard, stony corals like the reef-forming *Lophelia pertusa* and solitary cup corals (e.g. *Desmophyllum dianthus*, *Flabellum* spp.). Most shallow-water Scleractinians are colonial while most deep-sea species are solitary (Cairns 2007). Scleractinians have skeletons made of aragonitic calcium carbonate and polyps have variable numbers of tentacles and paired mesenteries, but always the same number of each (Roberts et al. 2009). Antipatharian polyps have 6, 10 or 12 complete, unpaired mesenteries but always have six tentacles (Roberts et al. 2009). Local representatives of Antipatharians include *Stauropathes artica* and *Bathypathes patula*. While Octocorals and Scleractinians have species that are solitary or colonial, all Antipatharians are colonial.

1.2.2 Feeding

There is little information on the physical processes by which deep-sea corals receive food particles. However, their occurrence can be related to primary productivity by surface phytoplankton, zooplankton production and local hydrography (Roberts et al. 2009). Deep-sea corals are benthic sessile filter feeders that feed on food particles in the water column. These food particles may include zooplankton and/or particulate organic matter (POM) (Sherwood et al. 2005, Sherwood et al. 2008).

1.2.3 Reproduction

Our understanding of the mechanisms by which deep-sea corals reproduce has grown in the past decade, but much remains unknown about the life histories of particular species. As a group, deep-sea corals show a variety of reproductive strategies. Some species have individuals of separate sexes (gonochoric) while others are hermaphroditic (Roberts et al. 2009). Deep-sea corals also have various modes of reproduction with some species spawning directly into the water column and others brooding their larvae internally (Roberts et al. 2009, Mercier et al. 2011). Some recent studies have shed some light on the reproductive strategies used by deep-sea corals including the timing of larval release, planula behavior, initial settlement and early juvenile growth (Sun et al. 2010a, Sun et al. 2010b, Mercier et al. 2011, Sun et al. 2011).

1.2.4 Environmental controls on deep-sea coral distribution

Temperature is one of the most significant environmental controls on deep-sea coral distribution. Equally important is the presence of appropriate substrate on which to settle, secrete a basal holdfast and build their skeleton (Mortensen & Buhl-Mortensen 2005, Roberts et al. 2009, Edinger et al. 2011). Some deep-sea corals, such as *Flabellum* solitary cup corals, live unattached on soft bottoms but the larvae of these species still need to attach themselves to a hard substratum initially; however small (Roberts et al. 2009).

Deep-sea corals are usually found in water 0-12^{o}C and some species are more tolerant to temperature fluctuations than others. Deep-sea corals require a constant or periodic flow of water for food and oxygen supply, the removal of sediments and wastes and for gamete and larval dispersal. Thus it is common to find concentrations or aggregations of deep-sea corals on ridges or rocky outcrops where currents are accelerated (Roberts et al. 2009). Recent habitat modeling suggests oxygen levels may influence distributions over a large geographical scale (Leverette & Metaxas 2005, Bryan & Metaxas 2006, Bryan & Metaxas 2007) and temporal scale (Thiagarajan et al. 2013), but less so on a local scale (Roberts et al. 2009).

Another potential determinant of deep-sea coral distribution is the depth of the Aragonite Saturation Horizon (ASH). The ASH is the depth below which corals and other calcifying marine organisms have greater difficulty extracting $CaCO_3$ from the water column. Recent evidence suggests that the ASH may be a limiting factor in the distribution of Scleractinian deep-sea corals (Guinotte et al. 2006).

In summary, the most significant environmental controls on deep-sea coral distributions are appropriate temperatures, salinities, appropriate substratum for initial attachment, and currents (Roberts et al. 2006, Roberts et al. 2009).

1.2.5 Global & local distribution of deep-sea corals

Most occurrences of deep-sea coral are first discovered as fisheries bycatch (Cairns 2007). The true extent of the abundance and distribution of deep-sea corals worldwide began to be revealed once governments started exercising control over their Exclusive Economic Zones (EEZ) and it became necessary to map seafloor territories in greater detail (Roberts et al. 2009). Deep-sea corals are found worldwide in a diverse range of deep-sea habitats including continental shelves and slopes, offshore banks and seamounts and even in the abyssal plain (Roberts et al. 2009). Some species such as the Scleractinian *Lophelia pertusa*, the nephtheid soft coral *Gersemia rubiformis* and the gorgonian, *Primnoa pacifica*, have also been found at much shallower depths in fjord systems in Norway, Newfoundland, Chile and New Zealand and Alaska (Roberts et al. 2009, Edinger et al. 2011, Waller et al. 2014). Fjords are an exception as some shallow-water fjord systems have similar oceanographic features to those of much deeper water and the term “deepwater emergence” has been used to describe this phenomenon (Waller et al. 2014).

Globally, the highest concentration of deep-sea (azooxanthellate) corals occurs on the continental shelves and slopes between the depths of 200-1000m (Roberts et al. 2009). These continental margins support both the highest abundance and highest diversity of deep-sea corals. Similarly in Atlantic Canada, the highest abundance and diversity of corals occurs on the continental shelves and slopes. From previous mapping efforts we know the highest concentrations are found along the continental slopes of the Labrador Shelf, the Grand Banks and the Scotian Shelf (Gass & Willison 2005, Wareham & Edinger 2007, Cogswell et al. 2009, Wareham 2009).

1.3 DEEP-SEA CORAL HABITATS

Different species of deep-sea coral provide habitats of varying physical sizes and life spans. (Roberts et al. 2009). For example, gorgonians, while being non-reef-forming can grow close together and form dense forest-like habitats. In fact some gorgonians grow in such high densities that fish harvesters in Atlantic Canada refer to them as “trees” and areas where they grow as “forests” (Gass & Willison 2005).

The greatest densities of non-reef-forming deep-sea corals worldwide are found in the northwest Pacific Ocean in an area known as the Aleutian coral gardens. Stone (2006) reported gorgonian densities of 0.84 colonies/m^2, which is up to an order of magnitude greater than the density of gorgonians found in Norway and Atlantic Canada (please see Table 1.1). Mortensen and Buhl-Mortensen (2004) reported that normal densities of gorgonians in Atlantic Canada are between 0.005-0.048 colonies/m^2.

Unlike reef-forming Scleractinian corals, when most species of gorgonians die their skeletons will break down rather than leaving behind carbonate reef frameworks (Roberts et al. 2009). Larger, long-lived gorgonians are an exception as their skeletons can provide structural habitat for some time after death (Roberts et al. 2009, Edinger & Sherwood 2012).

Table 1.1: Gorgonian densities recorded in the northwest Pacific, northeast and northwest Atlantic oceans

Area	**Study**	**Gorgonian density (colonies/m^2)**
Northwest Pacific Ocean	Stone (2006)	0.84
Norway	Mortensen et al. (2005)	0.043-0.069
Atlantic Canada	Mortensen and Buhl-Mortensen (2004)	0.048

1.3.1 Species associations with deep-sea corals

Studies which have looked at species associations with deep-sea corals and their associated fauna have shown evidence that deep-sea corals are as ecologically important as shallow-water coral systems by providing structurally complex habitats for a variety of marine species (Krieger & Wing 2002, Roberts et. al 2009, Buhl-Mortensen et al. 2010, Watling et al. 2011). In the deep sea, biogenic structures that reach even a few centimeters into the water column can be utilized by a variety of marine organisms (Watling et al. 2011). Deep-sea corals found on the continental margins act as biogenic substrates that can serve as resting, feeding and spawning sites for other species (Costello et al. 2005, Buhl-Mortensen et al. 2010, Watling et al. 2011).

Gorgonian assemblages appear to support fewer megafaunal species than Scleractinian reef-forming deep-sea corals (Roberts et al. 2009). This is likely because reef-forming corals, such as *Lophelia pertusa*, provide greater surface areas and diversity of habitats for other species (Metaxas & Davis 2005). In Atlantic Canada, Buhl-Mortensen and Mortensen (2005) collected 25 gorgonians (*Paragorgia arborea* and *Primnoa redaeformis*) and found 4000 individuals of 114 different species on the corals themselves.

In another study on *Primnoa* spp. in the Gulf of Alaska, Krieger & Wing (2002) found ten megafaunal groups associated with the gorgonian corals. These included six species of rockfish (*Sebastes* spp.), sea stars, basket stars, sea anemones, gastropods, and crustaceans (shrimp and crab). All of these organisms were found to use the coral for protection or as a substrate upon which to suspension feed. Sea stars and possibly also nudibranchs were observed actually feeding on the *Primnoa* corals themselves (Krieger & Wing 2002).

One of the main characteristics of shallow-water corals is the high diversity of fish species they support (Sale 1991, 2006). Deep-sea coral habitats are associated with fewer species of fish than shallow-water corals. This follows the general overall decline in fish diversity with increasing depth (Roberts et al. 2009). And like many other aspects of our knowledge on deep-sea corals, our understanding of the habitat they provide for species of fish is greatly limited by a lack of data. However, correlative studies and predictive models have shown increasing adult fish densities and sizes around deep-sea corals compared with areas having no coral (Husebø et al. 2002, Auster 2005) and distributional data have pointed to the possible importance of soft corals, small gorgonians and sea pens as fish habitat (Edinger et al. 2007b, Baillon et al. 2012, Baillon 2014).

It has been suggested that the deep-sea corals may be used as nursery grounds for fish (Etnoyer & Warrenchuk 2007, Buhl-Mortensen et al. 2010). In a recent study, Baillon et al. (2012) found direct evidence that commercial species of fish were using sea pens and sea pen meadows as nursery grounds. There have also been studies which have found species of commercial and non-commercial fish species to be larger in size and are more abundant in areas where deep-sea corals are found (Fosså et al. 2002, Husebø et al. 2002).

1.4 THREATS TO DEEP-SEA CORALS

Deep-sea corals have the potential to be impacted by any activity that comes into contact with the seafloor. The biggest threat to deep-sea corals is the commercial fishing industry (Roberts et al. 2009). The offshore oil and gas industry is an emerging threat, although in certain circumstances, oil drilling platforms may provide hard substrates to deep-sea corals in environments where these are scarce, such as the North Sea (Gass & Roberts 2006). Rising sea temperatures and ocean acidification resulting from global climate change may leave deep-sea corals vulnerable as less calcium carbonate ($CaCO_3$) is available in the water column for building resilient skeletons (Roberts et al. 2009).

1.4.1 Bottom fishing

Following the collapse of shelf fisheries in the mid twentieth century, the fishing industry has moved progressively into deeper waters. Technology has allowed fish harvesters to target new deep-water species resulting in fishing activity on most of the world's continental shelves, slopes, offshore banks and seamounts (Watling & Norse 1998, Roberts et al. 2009).

Ever since fish harvesters started using gear that came into contact with the seafloor there have been reports of the bycatch of deep-sea coral, sponges and other benthic invertebrates (Roberts et al. 2009). However, it was the invention of the bottom trawl that was a real game changer. Bottom trawling, where large nets and rollers are repeatedly dragged along areas of the seafloor, is an extremely effective way of catching deep-sea fish. Bottom trawling also kills or damages non-target also kills or damages non-target species as bycatch, which among other things, allows scientists to map distributions of deep-sea corals and sponges through fisheries bycatch (Breeze et al. 1997, Fosså et al. 2002. Gass & Willison 2005, Wareham & Edinger 2007, Edinger al 2007a)

Historically fish harvesters using bottom trawls avoided fishing on rough bottom, including some areas now known to contain deep-sea coral, as doing so could result in damaged or lost gear. It is also very time consuming to pull coral out of netting. But as fishing vessels grew in size, trawl nets were outfitted with gear modifications, such as 'rockhoppers', which allowed them to fish rougher bottoms (Watling & Norse 1998). The effect of sediment resuspension from trawl doors on deep-sea corals is unknown, however, such exposure to sediment has the potential to smother or stress corals, especially those found on soft bottoms such as sea pens (Pennatulacea) and Scleractinian cup corals such as *Flabellum* sp. (Roberts et al. 2009).

Coral bycatch is not unique to bottom trawling. Any type fishing gear (i.e. gillnet or longline) that comes into contact with the seafloor has the potential to damage or remove deep-sea corals (Breeze et al. 1997, Gass & Willison 2005, myers, Edinger et al. 2007a). While some gears are thought to have less impact than others (Chuenpagdee et al. 2003, Fuller et al. 2008), all bottom-fishing gear types should be considered when examining the impact of fishing on deep-sea coral habitats.

1.4.2 Oil & gas exploration and development

The oil and gas industry is also exploiting reservoirs in progressively deeper waters. Technological innovations such as floating production platforms, riser systems and seabed-mounted pumping stations have allowed oil companies to move down the continental slope and drill in deep waters (Roberts et al. 2009).

The impacts of oil and gas exploration and development are more restricted in their extent than the widespread effects of bottom-fishing. However, hydrocarbon prospecting and extraction in the deep-sea and the drill cuttings and tailings associated with extraction and the spill have the potential to smother benthic suspension-feeding organisms like corals (Roberts et al. 2009). Oil spills may have less drastic effects on deep-sea corals than shallow-water tropical reefs (White et al. 2012) but still pose a threat to deep-sea corals and other marine life found in or near drill sites (Roberts et al. 2009, DFO 2013).

There are significant oil and gas projects currently underway in Atlantic Canada, such as the Deep Panuke, Hibernia, White Rose and Terra Nova developments (Industry Canada 2009). The most exploration and development has been on the Grand Banks and Scotian Shelf. There is now, however, exploration in the Northern Gulf of St. Lawrence in an offshore area off the southwest tip of the island of Newfoundland in the Laurentian

Channel known as Old Harry. There are six proposed drilling sites at Old Harry, with one exploratory well planned for 2014 (DFO 2013).

1.4.3 Climate change & ocean acidification

All marine organisms that use calcium carbonate ($CaCO_3$), including deep-sea corals, are facing an uncertain future as seawater is warming and carbon dioxide (CO_2) is being absorbed by the world's oceans (Roberts et al. 2009). Rising sea surface temperatures are changing the distribution ranges of many species, especially in shallow waters. In the deep sea temperature changes less but there is a greater change in pH (Guinotte et al. (2006) and increasing levels of CO_2 are causing the world's oceans to gradually become more acidic. Surface ocean pH has declined from 8.21 to 8.1 since the industrial revolution (Caldeira & Wickett 2003, Feely et al. 2008). pH is on a logarithmic scale and this decrease of 0.11 roughly represents a 30% increase in the concentration of hydrogen ions (H^+) resulting in a 30% increase in acidity (Roberts et al. 2009).

Deep-sea corals are affected by anthropogenic CO_2 release through the combined effects of increasing seawater temperatures due to climate change and progressive ocean acidification as a result of this CO_2 dissolving in the oceans (Roberts et al. 2009). Studies such as Fabry et al. (2008) look at the impacts of ocean acidification on marine fauna and ecosystem processes in general. However, there is no consensus about how corals may respond to decreased aragonite saturation states (Roberts et al. 2009). Orr et al. (2005) modeled the effects of CO_2 release on the carbonate saturation state of the world's oceans. These projections were used by Guinotte et al. (2006) to predict that 70% of reef-forming deep-sea corals would be in under-saturated seawater with respect to $CaCO_3$ availability if the predictions by Orr et al. (2005) are correct. Roberts et al. (2009) also suggest that corals calcifying in cold, deep waters may be among the first to feel the effects of changing carbonate saturation state in the world's oceans. Further research is needed on the effects of ocean acidification on deep-sea corals (Roberts & Cairns 2014) as studies, such as Andersson et al. (2008), have shown evidence for the vulnerability of deep-sea corals found in higher latitudes and colder waters to ocean acidification.

1.5 FISH HARVESTER LOCAL ECOLOGICAL KNOWLEDGE (LEK) AND KNOWLEDGE OF DEEP-SEA CORALS

The previous sections of this thesis introduced deep-sea corals, their biology, the habitats they provide and current threats they are facing. The following sections introduce local ecological knowledge, its use in previous studies and its inclusion in scientific research and management decisions. This current study recorded the LEK of fish harvesters on deep-sea coral bycatch in the Northern Gulf of St. Lawrence (4RS3Pn) which will be presented in Chapters Two and Three of this thesis. Following the introduction to LEK, there is a section on the Northern Gulf of St. Lawrence; the study area of this current project, and an introduction to Northern Gulf commercial fisheries.

Marine biologist Bob Johannes published the first major study on the potential and often overlooked ecological knowledge of fish harvesters more than 30 years ago. In *Words of the Lagoon*, Johannes (1981) argued that natural scientists had routinely overlooked the expert knowledge of local resource users. He further argued that this omission was a result of the elitism and ethnocentrism that ran deep in the scientific community at the time of his study. The purpose of his book was to elucidate what practitioners of western science can learn by using information gleaned from working with indigenous fish harvesters about marine resources and ecosystems by investigating the knowledge and actions of native fish harvesters. During his time in the Palau district of Micronesia, Johannes gained more information new to science than he had during the previous 15 years using more conventional research techniques.

Since the time of Words of the Lagoon, researchers from both the natural and social sciences have recognized the value and depth of local ecological knowledge (LEK).The expert knowledge of local resource users, including commercial fish harvesters, is a form of LEK which is defined as the knowledge held by a group about their local ecosystem (Olsson & Folke 2001). Studies such as Neis et al. (1999) demonstrate how personal, career-history interviews, supplemented by follow-up meetings can yield large amounts of information from fish harvesters useful for fisheries assessment. Using the information gained during interviews with fish harvesters, Neis et al. (1999) were able to gather information on stock distinctiveness, changing fishing efficiency, landings and catch per unit effort (CPUE) of Atlantic cod (*Gadus morhua*) stocks in Bonavista and Trinity Bays, located on the northeast coast of Newfoundland.

In the context of wildlife management, the purpose of collecting LEK is to seek out and apply any reliable information, including information collected independently of western science in making informed management decisions (Gilchrist & Mallory 2007). Including LEK in such decision-making processes, can improve efforts to understand and address population declines, especially as a result of human activity (Gilchrist & Mallory 2007). The use of LEK has many applications and it has been used effectively in a wide array of studies from land-cover changes in South Africa (Chalmers & Frabricius 2007) to sea turtle conservation in Central America (Moore et al. 2010). In the Canadian Arctic, LEK along with scientific assessments were used to study and monitor populations of the endangered Ivory gull (*Pagophila eburnea*) and to monitor trends in populations of Arctic seabirds with the help of the local Inuit communities (Robertson et al. 2007, Gaston et al. 2012).

The knowledge of local resource users has been found to complement and even enhance existing scientific knowledge in the proper context (Maurstad et al. 2002). For example, in another study on Atlantic cod, Murray et al. (2008) compared the LEK of fish harvesters with the scientific information available on cod migration in the Northern Gulf of St. Lawrence. They found that when these two sources of information were used together a more accurate picture of migration patterns and stock structure appeared. In the Gulf of Maine, interviews with older and retired fish harvesters produced maps of current and past spawning areas for cod and haddock (*Melanogrammus aeglefinus*) and highlighted local fisheries impacts such as the collapse of local cod stocks (Ames 1998) not otherwise documented.

1.5.1 Using local ecological knowledge in science and management

There are trade-offs when using LEK such as lower precision with reference to location of encounter (latitude and longitude) and lower taxonomic resolution in identifying species. However, it is clear that LEK can provide a valuable source of information when transparent, rigorous methodologies are used; especially in data-poor situations where other sources of information are unavailable (Boudreau & Worm 2010).

Describing research methods in a detailed manner is standard practice in scientific research and enhances the ability of other researchers to learn from the mistakes and build on the strengths of the methods used in previous similar studies. While LEK is recognized to be different than scientific knowledge (Nadasny 1999, Berkes et al. 2000, Huntington 2000, Moller et al. 2004), such practices would help ensure more rigorous research methodologies. Davis and Wagner (2003) found that researchers, even in particular case studies, failed to provide detailed descriptions of the methods they used, in particular in how experts were identified and how participants were selected

Recent reviews of the LEK literature (Davis & Wagner 2003, Davis & Ruddle 2010) recommend improvements in the following areas: (1) identifying experts when looking for interview participants, (2) using systematic research designs so that the results of multiple studies can be compared, (3) improvement in the reporting of the methods used, and (4) making results open to public scrutiny and evaluation in terms of data reliability and representation.

Davis and Wagner (2003) deeply emphasize the need for properly identifying experts when conducting interviews in LEK research. They suggest that peer referencing, using snowball sampling (Goodman 1961), is effective in identifying local experts. This is a standard technique in recruiting study participants in the social sciences (Newman 2000). Davis and Ruddle (2010) also further argue that failing to adhere to these recommendations does not advance the interests of local resource users and may expose them to increased risk and vulnerability.

1.5.2 Local ecological knowledge and deep-sea corals

As mentioned above, the majority of studies using LEK have focused on species which are commercially-fished. However, because of both the high costs associated with deep-sea research, the limited existing research on deep-sea corals, and the emergent relationship between deep-sea fisheries and deep-sea coral degradation, fish harvesters' LEK has often been used in studies on deep-sea corals, especially distributions (i.e.

Breeze et al. 1997, Fosså et al. 2002, Gass & Willison 2005, Edinger et al. 2007, Sampaio et al. 2012). In general, information gathered from fish harvesters has allowed researchers to allocate their resources more effectively and to direct future research efforts to areas of perceived importance. For example, some deep-sea coral hot spots identified off Newfoundland and Labrador by Edinger et al. (2007) were first suggested as areas of interest by local fish harvesters (Gass & Willison 2005). Here coral hot spots refer to areas where deep-sea corals are abundant or have high levels of diversity (Breeze & Fenton 2007).

The knowledge of fish harvesters on both deep-sea coral distribution and the impacts of fishing activities on corals allow information not otherwise available to be included in management decisions. Studies such as Fosså et al. (2002), Gass (2002), Gass and Willison (2005) and Sampaio et al. (2012) provide successful examples of using LEK research methodologies to study marine species that are not commercially fished. For example, when trying to determine the extent of damage to *Lophelia pertusa* reefs off Norway, Fosså et al. (2002) relied heavily on information gathered from local fish harvesters to determine that 30-50% of the *L. pertusa* reefs had been damaged or impacted from bottom trawling.

Gass (2002) conducted interviews with fish harvesters to determine the distribution of deep-sea corals in Atlantic Canada. During semi-structured interviews, fish harvesters were asked about coral species/groups they had observed as bycatch, any changes in the amount of coral bycatch observed over time, and target fisheries and gear types where coral bycatch was observed. Further, the LEK of fish harvesters, accessed through interviews, provided the first records for Antipatharians corals in Atlantic

Canada and future research efforts, including DFO survey trawls and ROV (remotely-operated vehicle) exploration, were suggested based on the observations of fish harvesters (Gass 2002, Gass & Willison 2005).

Sampaio et al. (2012) interviewed fish harvesters in the Azores to confirm that deep-sea corals are commonly caught as bycatch in local longline fisheries. During the interviews the authors were able to confirm which species are seen most commonly as bycatch as well as to determine that there had been a decrease in coral bycatch over time in these fishing areas.

This thesis uses LEK to study deep-sea coral distributions in the Northern Gulf of St. Lawrence and to understand how fish harvester LEK can contribute to science and management of deep-sea corals. The following section describes the characteristics of the Northern Gulf of St. Lawrence, with an emphasis on the Laurentian Channel, the deepest channel found in the Gulf, along with an introduction to Northern Gulf fisheries.

1.6 THE NORTHERN GULF OF ST. LAWRENCE

The Gulf of St. Lawrence is a semi-enclosed sea bounded on the north by Labrador and Quebec, to the east by the island of Newfoundland, to the south by Nova Scotia and Cape Breton Island and to the west by the Gaspé Peninsula and New Brunswick. The three largest islands in the Gulf are Cape Breton Island, Prince Edward Island and Anticosti Island. The Gulf is connected to the Atlantic Ocean via the Strait of Belle Isle, the Strait of Canso and the Cabot Strait.

The Northern Gulf of St. Lawrence lies on the continental shelf; therefore, we would expect less coral diversity than on the continental slope which has a greater range of coral-suitable habitats (Wareham & Edinger 2007). While the majority of the Northern

Gulf is less than 200m deep, the Esquiman and Anticosti Channels are deep-water channels that contain Labrador slope water that remains above $0^{o}C$ year-round (DFO 2005, Galbraith et al. 2013). The sides of these channels have steep slopes that could provide appropriate substrate for deep-sea corals. Sea pens, order Pennatulacea, are common on the continental shelves and margins of Atlantic Canada and require soft, muddy substrates to settle. The bottom of these deep channels would provide suitable habitat for sea pens.

1.6.1 The Laurentian Channel

The Laurentian Channel was formed during previous ice ages when sea levels dropped and the continental shelf was eroded by the outflow of the St. Lawrence River. It is approximately 290m deep and 1250km in length spanning the St. Lawrence Estuary at the mouth of the St. Lawrence River to the continental shelf edge at the Laurentian Fan (DFO 2005). The Laurentian Channel is the deepest channel in the Gulf of St. Lawrence. Deep bottom water (2-$6^{o}C$) enters the Gulf at the continental slope and is slowly advected up the channel by estuarine circulation (DFO 2005, Galbraith et al. 2013). Over the last century, the bottom waters in the St. Lawrence Estuary have become hypoxic and recent evidence suggests that there are now dead zones in the Northern Gulf of St. Lawrence, particularly in the St. Lawrence estuary and in the bottom waters of the Anticosti, Esquiman and Laurentian Channels (Benoît et al. 2012).The relationship between these dead zones and deep-sea coral distributions have not been studied.

1.6.2 Northern Gulf of St. Lawrence fisheries

First nations groups have lived on the shores of the Northern Gulf for millennia and have historically used the Northern Gulf for transportation and subsistence fishing.

The Northern Gulf also has a long history of commercial fishing. Parts of it were heavily trawled for groundfish prior to the moratorium on Northern Gulf cod stocks in 1994. Other areas in the Northern Gulf had intensive cod trap, longline and gillnet fisheries up until that time as well (Sinclair 1985).

Groups in a majority of the coastal communities located on the Northern Gulf of St. Lawrence remain active in the fisheries. Since the moratorium, bottom-trawling for cod has ceased but longlining and gillnetting for cod continues at a reduced temporal and spatial scale. Along with cod, many fish harvesters fish for Atlantic halibut (*Hippoglossus hippoglossus*) and Greenland halibut/turbot (*Reinhardtius hippoglossoides*) using the same or very similar gear. Some areas in the Northern Gulf, in particular off the west coast of Newfoundland in NAFO division 4R, have been and continue to be, heavily trawled for Northern shrimp (*Pandalus borealis*), particularly the Esquiman Channel. Shrimp trawling in the Northern Gulf began before the implementation of the Nordmøre grate[1],which began to be implemented in the early 1990's and has been mandatory for all Canadian shrimp trawling vessels in Atlantic Canada since 1992 (Richards & Hendrickson 2006). The Nordmøre grate is used in an attempt to reduce bycatch of non-target groundfish species (ICES 1996, Richards & Hendrickson 2006).

Since the moratorium, Northern Gulf fish harvesters have targeted a number of different species using various sized vessels and gear types. While very few Northern Gulf fish harvesters are involved in just one fishery, the main fisheries of the fish

[1]The Nordmøre grate is an aluminum grid attached to the otter trawls used by shrimp harvesters to reduce groundfish bycatch

harvesters interviewed for this study were Atlantic cod (using gillnets and longlines) and Northern shrimp (using bottom trawl).

1.7 THESIS STRUCTURE

Chapter One introduced deep-sea corals, species association with deep-sea coral habitats, threats facing deep-sea corals and factors affecting their global and local distributions. Local ecological knowledge was then introduced, as well as its previous use in scientific assessments of deep-sea corals. Finally, the Northern Gulf of St. Lawrence was then introduced with an overview of current and past commercial fisheries in the Northern Gulf.

The first objective of this current project was to determine which species/groups of deep-sea corals occur in the Northern Gulf of St. Lawrence and to map their distribution using all sources of information available. The three sources of information used to do this were DFO groundfish survey trawl and fisheries observer records of coral bycatch as well as the LEK of Northern Gulf fish harvesters on deep-sea coral bycatch. The second objective was to report the observations of fish harvesters on the occurrence of coral bycatch in Northern Gulf fisheries including factors affecting coral bycatch, changes in the amount of coral bycatch over time and the relationship between deep-sea corals and commercial fish species (including Northern shrimp) in the Northern Gulf. The third objective was to report the opinions of fish harvesters on the fisheries and gear types that produce the most coral bycatch, the importance of deep-sea corals and appropriate measures for protecting corals in the Northern Gulf of St. Lawrence. The two main content chapters of this thesis (Chapters Two and three) are written as stand-alone research documents. Chapter Two has been published as a DFO research document (see

Colpron et al. 2010).Chapter Two presents the findings on the distribution of deep-sea corals in the Northern Gulf focusing on the maps generated using the three sources of data; DFO survey trawl and fisheries observer records of coral bycatch and the LEK of fish harvesters. There is also a discussion on the potential relationship between sea pens (Pennatulacea) and some commercially-fished species including Atlantic cod (*Gadus morhua*), Atlantic halibut (*Hippoglossus hippoglossus*) and Northern shrimp (*Pandalus borealis*).

Chapter Three, which will be submitted for publication in a peer-reviewed scientific journal, provides an in-depth summary of the information recorded during interviews with Northern Gulf fish harvesters. This includes data on the demographics and fishing histories of the interviewed fish harvesters, their familiarity with deep-sea coral bycatch, and their responses to both observational and opinion-based questions on deep-sea coral bycatch in the Northern Gulf. Chapter Three also provides a discussion on the methods used to recruit participants and to conduct the interviews and feedback meetings.

Chapter Four summarizes the information presented in this thesis including the distribution, abundance and species richness of deep-sea corals in the Northern Gulf as reported in Chapter Two. There is also a summary of the fish harvesters' LEK on deep-sea coral bycatch in Northern Gulf fisheries that was reported in Chapter Three. Chapter Four concludes with recommendations for future research on deep-sea corals in the Northern Gulf and deep-sea coral protection in that region and related fisheries.

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CHAPTER TWO: MAPPING THE DISTRIBUTION OF DEEP-SEA CORALS IN THE NORTHERN GULF OF ST. LAWRENCE USING BOTH SCIENTIFIC AND LOCAL ECOLOGICAL KNOWLEDGE

ABSTRACT

While over 50 species of deep-sea coral have been identified in Atlantic Canada, little is known about the corals found in the waters off the west coast of Newfoundland and in the Northern Gulf of St. Lawrence in general. This study uses three sources of information to identify coral species found in the Northern Gulf (NAFO areas 4RS3Pn) and to map their distribution and abundance hot spots. Observations from DFO (Fisheries & Oceans Canada) groundfish survey records from the Gulf were combined with coral observations fisheries observer records of coral bycatch and mapped using ArcMap 9.3. Interviews were then conducted with a stratified sample of 28 Northern Gulf of St. Lawrence fish harvesters. These harvesters were considered 'experts' with greater than 20 years of experience and were asked which species of deep-sea corals they had seen come up in their gear as bycatch, and where possible, the location of these encounters. All three sources of data confirm that nephtheid soft corals are common in the Northern Gulf. DFO trawl survey records and information gathered during interviews with fish harvesters both suggest that sea pens are commonly found in the deep-water channels present in the Northern Gulf (Anticosti and Esquiman Channels). Records of large gorgonians are missing from the DFO trawl survey and fisheries observer records. However, during the interviews, *Primnoa resedaeformis*, *Keratoisis grayi* and *Acanthogorgia armata* were reported to be present in the Northern Gulf with limited

distributions. These large gorgonians were observed in longline gear, which can be deployed on rocky bottoms that cannot be sampled by the DFO groundfish trawl survey program. Interviewed fish harvesters described an association between high bycatch of sea pens and high catch rates of Northern shrimp, Atlantic cod and Atlantic halibut.

2.1 INTRODUCTION

The deep-sea corals of Atlantic Canada have recently received increased attention due to concerns raised about the impact of commercial fishing activities on benthic ecosystems (Watling & Norse 1998, Edinger et al. 2007a, Fuller et al. 2008). The slow growth and recruitment rates of deep-sea corals make them especially vulnerable to bottom fishing (Roberts et al. 2006, Roberts et al. 2009, Sherwood & Edinger 2009). Bottom fishing refers to deep-sea fisheries that use any gear type that may come into contact with the seafloor (Chuenpagdee et al. 2003, Edinger et al. 2007a, Fuller et al. 2008).

While coral distribution data exists for the continental margins of Atlantic Canada (i.e. Gass & Willison 2005, Wareham & Edinger 2007, Cogswell et al. 2009), there has been little done to map the distribution of deep-sea corals in the Northern Gulf of St. Lawrence, encompassing NAFO (Northwest Atlantic Fisheries Organization) divisions 4R, 4S and 3Pn (see Figure 2.1). The goal of this study was to fill in information gaps to determine the abundance, diversity and distribution of deep-sea corals in the Northern Gulf. Records of coral bycatch from DFO groundfish survey trawls and fisheries observer records were combined with information gathered during interviews with Northern Gulf fish harvesters to determine which species of deep-sea coral are present in the Northern Gulf, their distribution and potential fisheries impacts. This method is similar to that used by Gass & Willison (2005) in that we used three sources of information to map the distribution of deep-sea corals but is different in that nephtheid soft corals, such as *Gersemia rubiformis*, and sea pens (Pennatulacea) were considered in this current study.

Many communities on the Northern Gulf of St. Lawrence remain active in commercial fisheries and fish harvesters provide a wealth of knowledge coming from repeated, long-term interactions with the marine environment. Fish harvesters' knowledge of deep-sea corals is a valuable source of information, especially considering the high costs associated with deep-sea research. For example, coral hot spots explored by Edinger et al. (2007a) were first identified during fish harvester interviews conducted by Gass & Willison (2005).

The Northern Gulf of St. Lawrence lies on the continental shelf; therefore we would expect less coral diversity than on the continental slope, which has a greater range of habitats (Wareham & Edinger 2007).

In previously published data showing the global predicted habitat suitability of octocorals, Yesson et al. (2012) determined that large areas of the Gulf of St. Lawrence could provide suitable habitat for Alcyonacean corals which include soft corals and both small and large gorgonians. While the majority of the Northern Gulf is less than 200m deep, there are deep-water channels (Anticosti and Esquiman Channels) that contain slope water that remains above 0^{o}C year-round (see Figure 2.1).

These channels have steep slopes, suitable bottom temperatures, strong currents, and the high productivity in the Gulf, in general (Dufour & Ouellet 2007), would provide an ample supply of food for deep-sea corals. All of these factors are used in predictive modelling studies and are associated with suitable habitat for deep-sea corals (Bryan &

Metaxas 2007). Further, some species of deep-sea coral previously reported to occur in Atlantic Canada are able to live in soft, muddy substrates like those found at the bottom of these channels. These include sea pens (order Pennatulacea). Several recent studies have discussed the potential ecological importance of deep-sea corals for fish (Husebø et al. 2002, Krieger & Wing 2002, Auster 2005, Auster 2007, Edinger et al. 2007b). Many fish harvesters in the Northern Gulf have experience fishing for a variety of target species using various gear types and therefore may be able to provide information on any apparent relationships between deep-sea corals and fish. The Northern Gulf has a long history commercial fishing. Parts of it were heavily trawled for groundfish prior to the moratorium on Northern Gulf cod in 1994. Other areas had intensive coastal cod trap and deeper water gillnet and longline fisheries for groundfish until that time. Since the moratorium, bottom-trawling for groundfish has ceased. However, gillnetting and longlining for cod has continued at a much smaller spatial and temporal scale along with similar fisheries for other groundfish species such as Atlantic halibut (*Hippoglossus hippoglossus*) and turbot (*Reinhardtius hippoglossoides*), also called Greenland halibut.

The Northern shrimp (*Pandalus borealis*) fishery in the Gulf of St. Lawrence began in 1965 (DFO 2014) and the first 15 years were dedicated to exploration of the resource (Morin et al. 2014). During the 1980's the number of operators increased substantially, and even more so during the 1990's after the decline of groundfish stocks. Increased shrimp abundance and participation by fish harvesters who had previously fished for groundfish led to industry expansion (Morin et al. 2014).

While shrimp trawling in the Gulf began before the implementation of the Nordmøre grate, its use has been mandatory in the Northern shrimp fishery in Atlantic

Canada since 1992 (Richards & Hendrickson 2006). The Nordmøre grate is an aluminum grid attached to the otter trawls used by fish harvesters to reduce groundfish bycatch with trawling for shrimp (ICES 2006, Richards & Hendrickson 2006). Currently, some areas in the Northern Gulf continue to be heavily trawled for Northern shrimp, specifically in the Esquiman Channel (NAFO Division 4R) (see Figure 2.1).

Existing research suggests that all of these gears (shrimp trawl, gillnet and longline) can intercept and potentially damage deep-sea corals (Edinger et al. 2007a, Fuller et al. 2008).

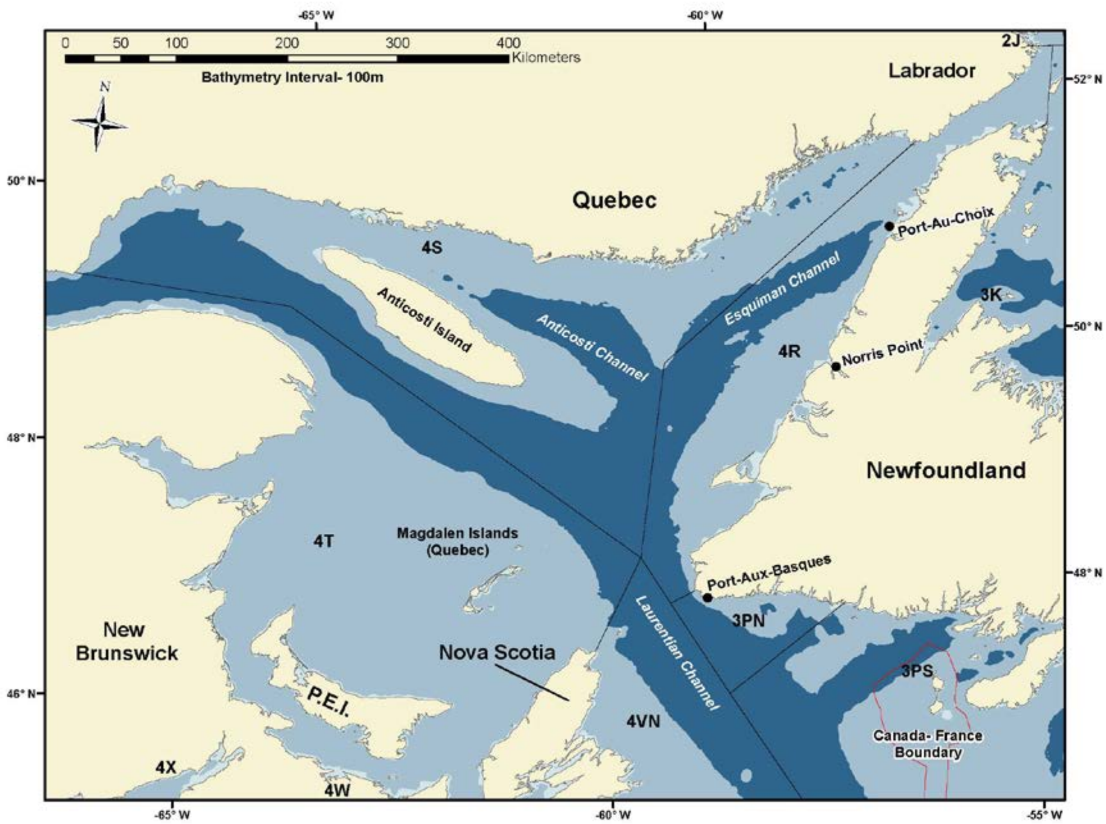

Figure 2.1: The Northern Gulf of St. Lawrence (encompassing NAFO divisions 4R, 4S and 3Pn)

2.2 METHODS

2.2.1 DFO Groundfish Survey Trawl Records

Records for all DFO groundfish survey trawls from 2001-2009 were obtained from DFO Quebec Region in Mont-Joli. These records include data on the presence and location of corals in the Northern Gulf, as well as, information on areas where no deep-sea corals were observed. Information included in the trawl survey data is location, depth, bottom temperature, salinity, identity, number of samples and biomass. Corals were identified to the best of the ability of the DFO groundfish technicians onboard using coral identification guides based on the ID guides developed by DFO Maritimes and Newfoundland regions. These data from the trawl surveys were imported and mapped using ArcMap version 9.3.

2.2.2 Fisheries Observer Records

Fisheries observer bycatch records for corals in the Northern Gulf of St. Lawrence were obtained from DFO Quebec Region for the years 2001-2008. While these records are not as comprehensive as those for the DFO groundfish survey trawls, information provided by the Fisheries Observer Program (FOP) included location, depth found, target species and gear types are included. Consistent with previous research, fisheries observer records are treated as presence data only, rather than presence-absence, as observers often do not have the ability to search each set for corals. Data from fisheries observer records were imported and mapped using ArcMap version 9.3.

2.2.3 Interviews with Northern Gulf of St. Lawrence Fish Harvesters

Interviews were conducted with 28 Northern Gulf of St. Lawrence fish harvesters in November and December 2009 in three communities on the west coast of Newfoundland. These communities were Port-Au-Choix, located on the Northern Peninsula of Newfoundland, Norris Point, located in the Bonne Bay area, and Port-Aux-Basques, located on the southwest tip of Newfoundland (see Figure 2.1). The number of fish harvesters interviewed in each community is indicated in Table 2.1. Port-Au-Choix was chosen because it is the home port of the Northern Gulf fleet of shrimp trawlers. Norris Point was chosen because fish harvesters in the Bonne Bay area target a variety of groundfish species including cod and turbot using both longlines and gillnets. Port-Aux-Basques was chosen as it is the home port of the longline fleet in NAFO division 3Pn (see Figure 2.1) members of which target both cod and halibut using longlines.

Table 2.1 Number of fish harvesters interviewed in each community (Northern Gulf of St. Lawrence)

Community	**Number of Interviews**
Port Au Choix	11
Norris Point	7
Port-Aux-Basques	10

2.2.3.1 Sample Recruitment

Contact was made with local elected representatives of the FFAW (Fish Food & Allied Workers) who provided names of potential interviewees in each community. At the end of each interview, we asked the interviewee for names of other local fish harvesters deemed to be experienced and knowledgeable about the Northern Gulf fisheries and marine ecosystem. This process of obtaining new names is known as snowball sampling (Goodman 1961) and is commonly used in local ecological knowledge (LEK) research (see Neis & Felt 2000). Fish harvesters', who were skippers of their own vessels, had more than 20 years of experience and that were deemed 'experts' by their peers (Davis & Wagner 2003) were targeted for this study.

2.2.3.2 Interviews

Semi-structured interviews were conducted where a fixed list of questions was asked during each interview with room for expansion to elaborate or discuss other topics that may come up during the interview. During the interviews, fish harvesters were asked to identify which species/groups of deep-sea coral they had observed as coral bycatch and, where possible, to place the locations of these encounters on a map. Further, harvesters were asked about their observations on the relationship between deep-sea coral bycatch and commercial fish species. Questions on the fish harvester's career, experience, target species, gear-types, impacts of different gears and opinions about conservation were also addressed and are presented in Chapter Three. During the interviews, in many cases, the fish harvester could identify species/groups of coral they had seen as bycatch but were unable to place the locations of these encounters on a map. In this chapter, when the location of coral bycatch was recorded, we will refer to this as a map-able observation versus an observation when only the coral was identified. The fish harvesters were not asked to map the fishing grounds where no coral bycatch had been observed. The interviews were not recorded. A research assistant typed up the interview transcripts while the interviews took place. The DFO identification guide for deep-sea corals in the Newfoundland & Labrador Region (see Appendix A) was used during the interviews along with preserved coral specimens from DFO Newfoundland Region.

2.2.3.3 Chart Drafting

Locations of fishing areas and coral distribution data were mapped directly into ArcMap© (version 9.3) during the interviews using a Lenovo tablet laptop. Harvesters were asked to draw polygons on nautical charts, obtained from the Canadian Hydrographic Service (CHS), representing their fishing areas and the areas where they encountered corals. These polygons were assigned numbers and were described in further detail in the interview transcripts.

2.3 RESULTS

A total of 11 deep-sea coral species/groups were recorded in the Northern Gulf of St. Lawrence. The greatest number of records came from the DFO groundfish survey trawl program, but the greatest diversity of species/groups was recorded in the interviews with fish harvesters

2.3.1 DFO Groundfish Survey Trawl Records

A total of 7,565 trawl records were obtained from DFO Quebec Region. These were records for both the presence and absence of coral for all sets from 2001-2009. While not all these records fall directly inside of NAFO divisions 4R, 4S and 3Pn, they were included when they were located close or inside of them. The majority (89%) of sets contained no coral bycatch (see Figure 2.2). Of the 11% (843/7565) of sets containing coral bycatch, 6% of sets contained sea pens (Pennatulacea spp.), 5% contained nephtheid soft corals and 0.05% contained *Anthomastus grandiflorus* (see Table 2.1) Coral biomasses for both sea pens and nephtheids were found to be highest in the Laurentian Channel (see Figure 2.3).

Table 2.2: Coral records in the Northern Gulf of St. Lawrence from DFO research survey trawls, fisheries observer records (FOR) and interviews with fish harvesters

Group	**Species**	**No. sets with coral (DFO) Total No. Sets = 7565**	**No. sets with coral (FOR)**	**No. identifications by Fish Harvesters Total No. Fish Harvesters = 28**	**No. Map-able observations from fish harvesters**
Alcyonacean soft corals	Nephtheid spp., (*Duva florida*, *Gersemia rubiformis*)	380	3	24	19
	Anthomastus grandiflorus	4	0	11	3
Sea pens	Pennatulacea spp.	459	0	16	10
Cup corals	Scleractinia spp.	0	0	6	1
Small gorgonians	*Acanella arbuscula*	0	0	3	0
	Radicipes gracilis	0	0	4	0
Large gorgonians	*Acanthogorgia armata*	0	0	11	3
	Antipatharia spp.	0	0	1	0
	Keratoisis grayi	0	0	3	3
	Paragorgia arborea	0	0	1	0
	Primnoa resedaeformis	0	0	6	2

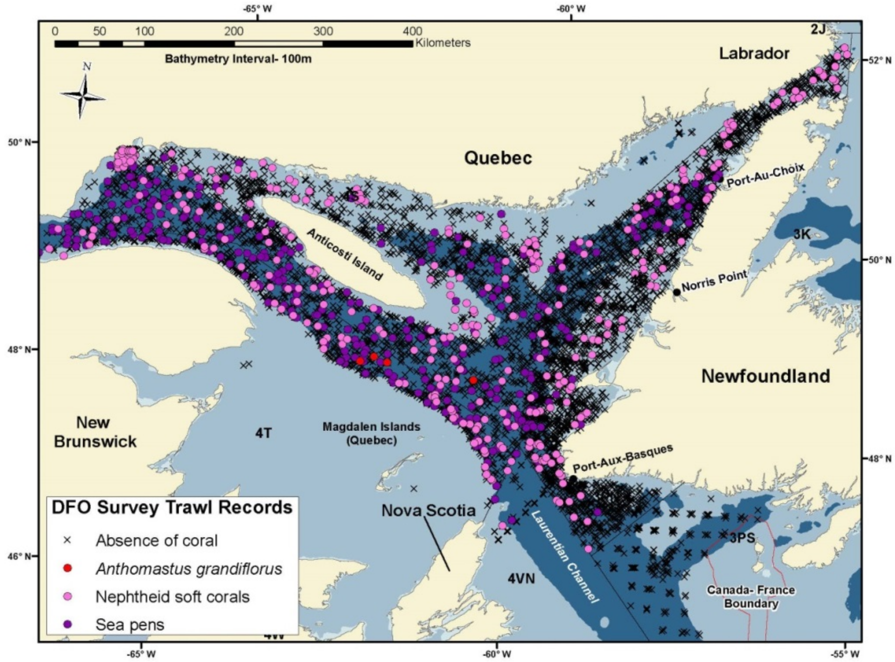

Figure 2.2: Presence and absence of deep-sea corals in the Northern Gulf of St. Lawrence from DFO research trawl surveys (2001-2009)

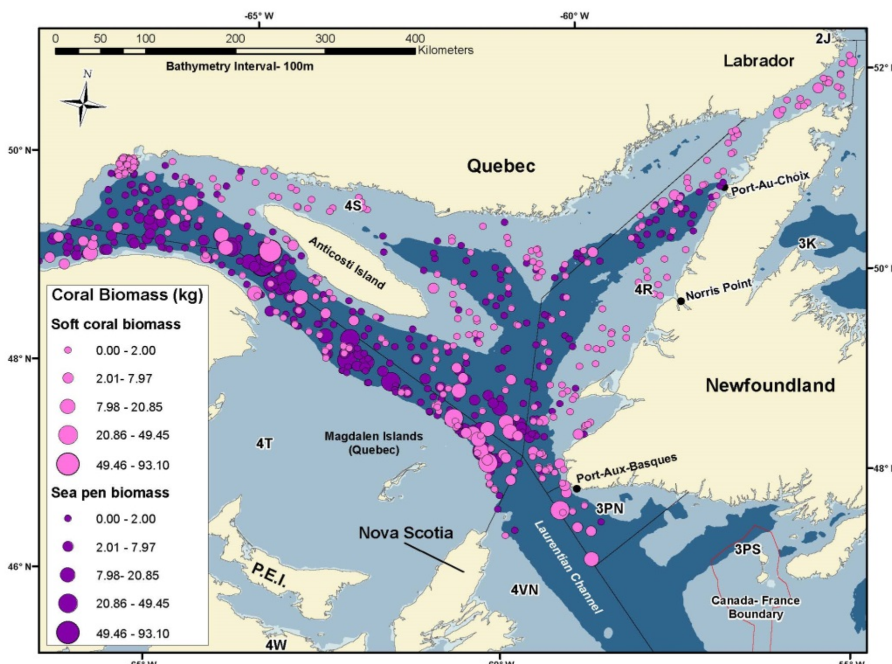

Figure 2.3: Deep-sea coral biomass in the Northern Gulf of St. Lawrence from DFO research trawl surveys (2001-2009)

2.3.2 Fisheries observer records

Fisheries observer records (2001-2008) contained 11 records of coral bycatch in the Northern Gulf of St. Lawrence and surrounding areas. All of these were for the nephtheid soft coral *Duva florida*. Only three of these records fall directly within the boundaries of the Northern Gulf, all in NAFO division 4S (see Figure 2.4).

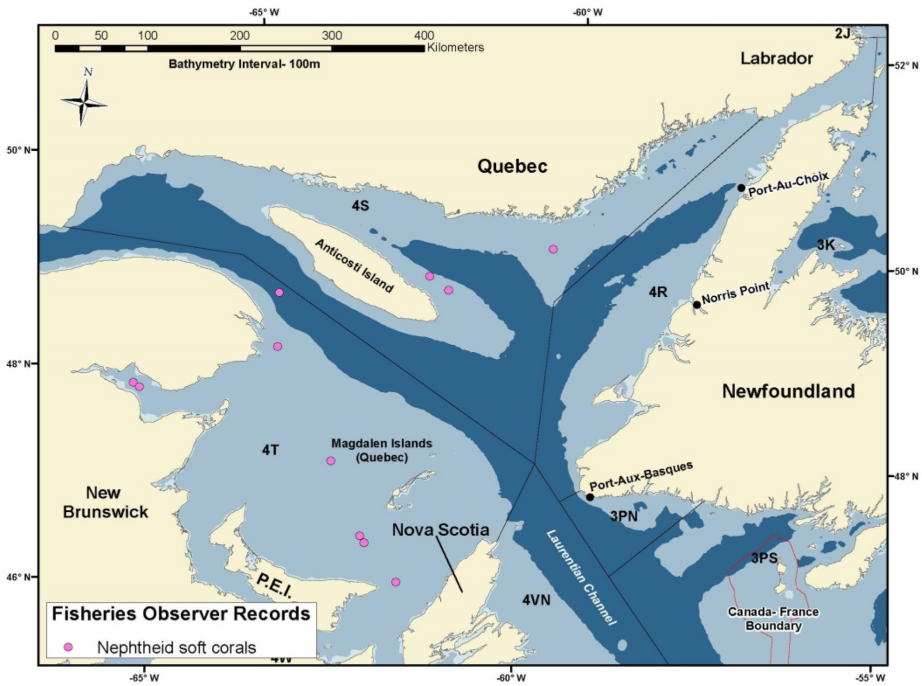

Figure 2.4: Fisheries observer records of coral bycatch in the Northern Gulf of St. Lawrence (2001-2008)

2.3.3 Interviews with fish harvesters

While we did not want to show the fishing grounds of individual fish harvesters, Figure 2.5 is a composite of the fishing grounds of all of the fish harvesters interviewed for this study. This figure shows that the fishing grounds of interviewed fish harvesters covered roughly half of the area of the Northern Gulf of St. Lawrence.

Eleven species/groups of deep-sea coral were identified by fish harvesters as species they had seen as bycatch. Nephtheid soft corals were the most common group reported by fish harvesters (85.7%) followed by sea pens (57.1%). As shown in Table 2.2, fish harvesters were more readily able to identify species/groups of deep-sea coral than to place the location of encounter on a map. For example, while 85.7% of interviewed fish harvesters were able to identify nephtheid soft corals, only 67.9% were able to place the area of encounter on a map and while 51.7% of fish harvesters were familiar with sea pens, only 35.7% were able to map their distribution. Maps were generated for 7 of the 11 species of deep-sea corals identified during interviews (see Figures 2.6- 2.12) including nephtheid soft corals, sea pens, *Anthomastus grandiflorus*, *Acanthogorgia armata*, *Keratoisis grayi*, *Primnoa resedaeformis* and Scleractininan cup corals. Four additional species/groups were identified during interviews, including the small gorgonians *Radicipes gracilis* and *Acanella arbuscula* and the large gorgonians *Paragorgia arborea* and Antipatharia spp., but the exact areas of encounter were not known.

2.3.4 Ecological interactions between sea pens and fish

43% (12/28) of the interviewed fish harvesters identified areas containing sea pens in the Northern Gulf to be good fishing grounds for a variety of commercial species including Atlantic cod (*Gadus morhua*), Atlantic halibut (*Hippoglossus hippoglossus*) and Northern shrimp (*Pandalus borealis*) using multiple gear types (gillnet, longline and shrimp trawl). The information presented below is based on the observations of the 12 fish harvesters who had identified sea pens as bycatch.

In the Esquiman Channel, fish harvesters reported that Northern shrimp were more abundant in areas off Port Au Choix that contained sea pens than surrounding areas that did not and reported better catches in the former areas. Shrimp trawlers in the Northern Gulf use a bottom trawl outfitted with a Nordmøre grid to reduce groundfish bycatch. Even using the Nordmøre grid, it was reported that sea pens are still commonly caught as bycatch.

Fish harvesters from the Port-Aux-Basques area also identified areas containing sea pens to be good fishing grounds for cod and halibut. The harvesters in this area (NAFO division 3Pn) use longlines to fish cod and halibut at depths suitable for sea pens. They reported that sea pens are commonly hooked on these longlines and brought up as bycatch. 90% of the harvesters interviewed in 3Pn, all of them longliners, reported that halibut found in areas containing sea pens were more abundant and larger in size than surrounding areas that did not contain sea pens. In particular, one harvester reported specifically targeting sea pen meadows for setting his gear because of previous success fishing in these areas.

Catch data for a variety of fish species, both commercial and non-commercial should be compared with available deep-sea coral abundance and distribution data for the Northern Gulf of St. Lawrence. A similar comparison, done on the continental margins of Newfoundland and Labrador, of catch rates and the rate of deep-sea coral bycatch found that sea pens and nephtheid soft corals may provide important habitat for both witch flounder (*Glyptocephalus cynoglossus*) and Northern shrimp, respectively (Edinger et al. 2007b).

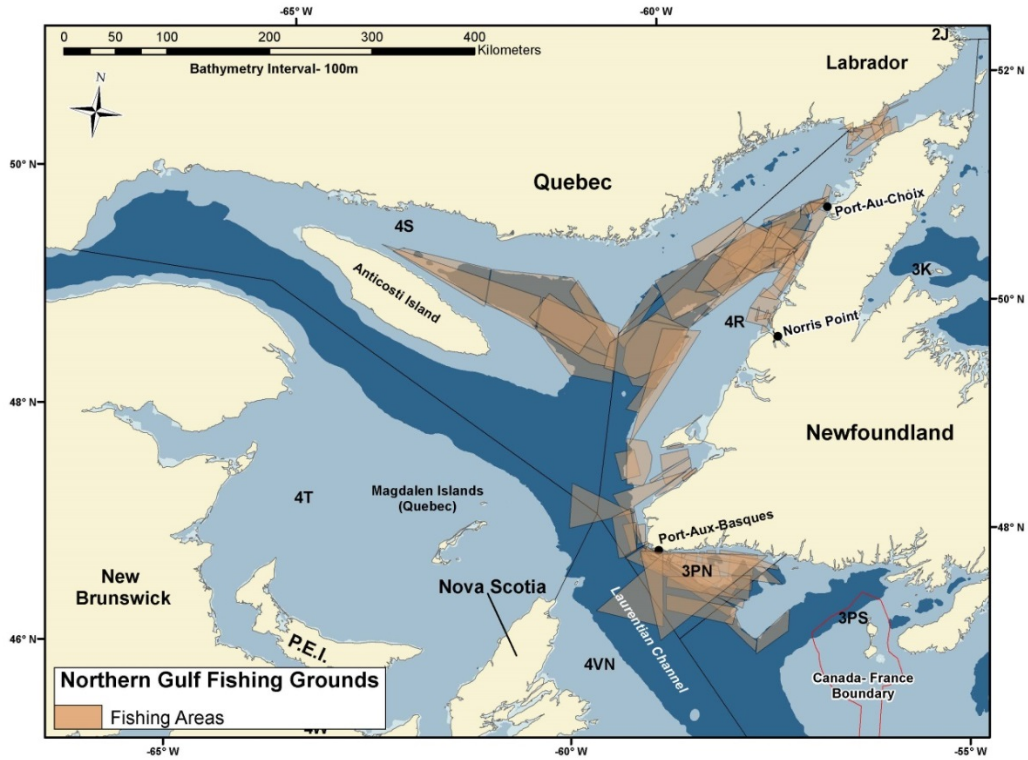

Figure 2.5: Fishing grounds of interviewed Northern Gulf of St. Lawrence fish harvesters

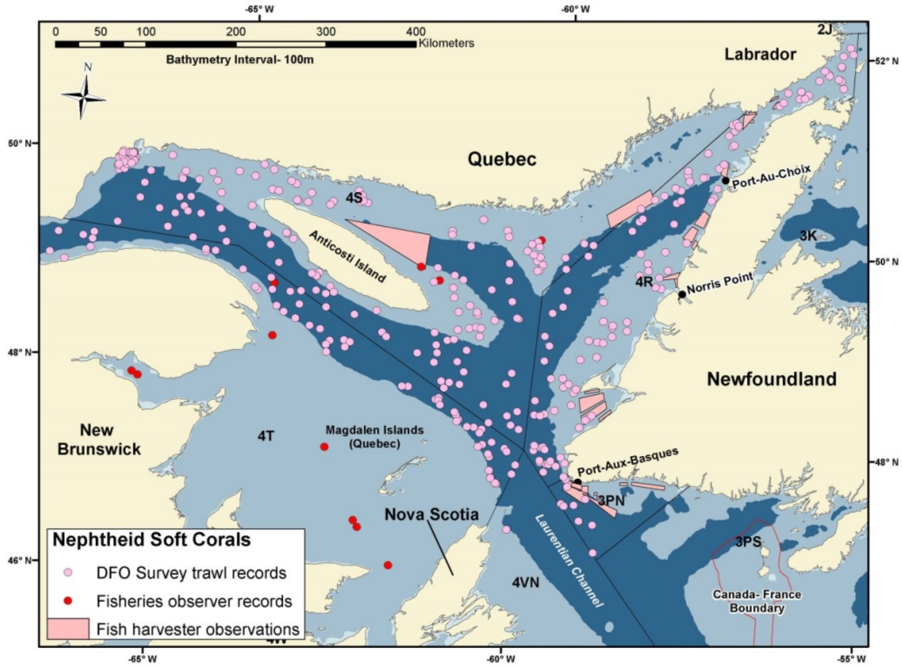

Figure 2.6: Distribution of nephtheid soft corals in the Northern Gulf of St. Lawrence from DFO research trawl surveys, fisheries observer records and fish harvester interviews

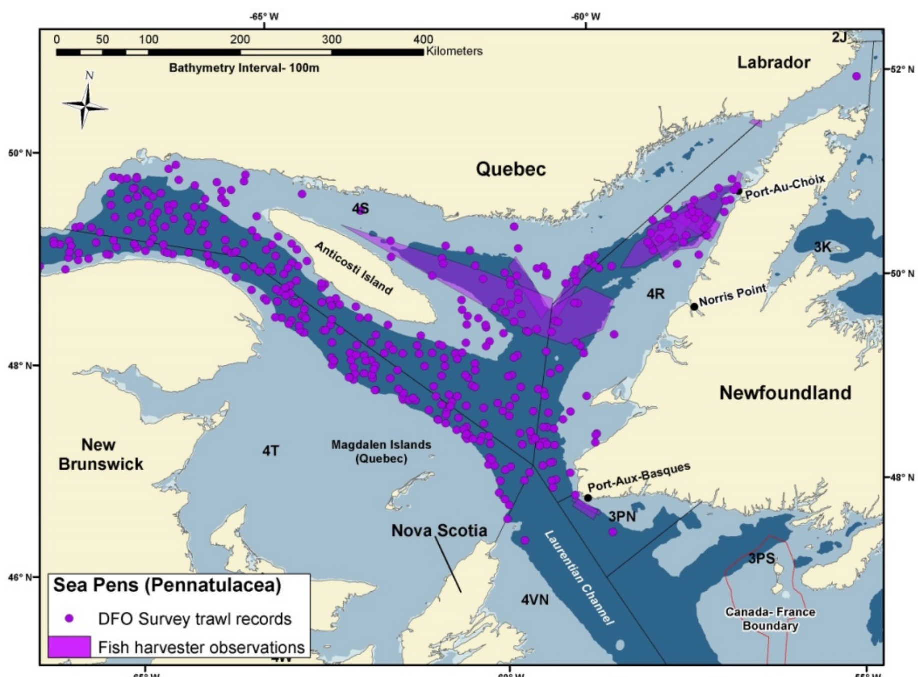

Figure 2.7: Distribution of sea pens in the Northern Gulf of St. Lawrence from DFO research trawl surveys, fisheries observer records and fish harvester interviews

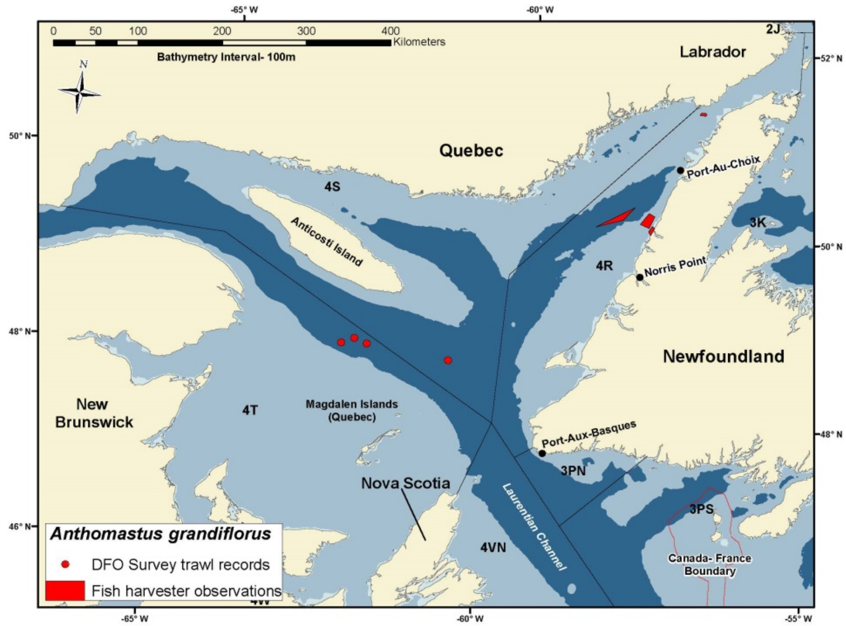

Figure 2.8: Distribution of *Anthomastus grandiflorus* in the Northern Gulf of St. Lawrence from DFO research trawl surveys, fisheries observer records and fish harvester interviews

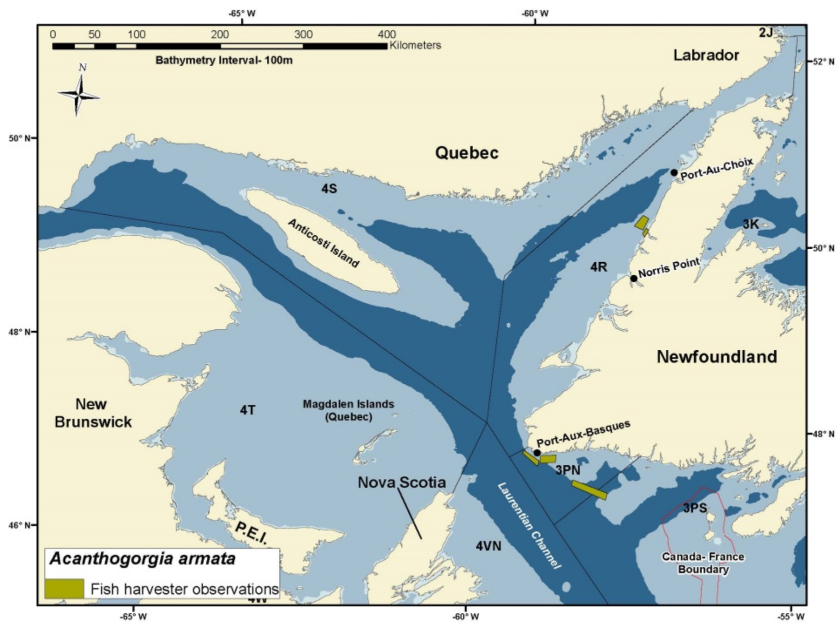

Figure 2.9: Distribution of *Acanthogorgia armata* in the Northern Gulf of St. Lawrence from interviews with fish harvesters

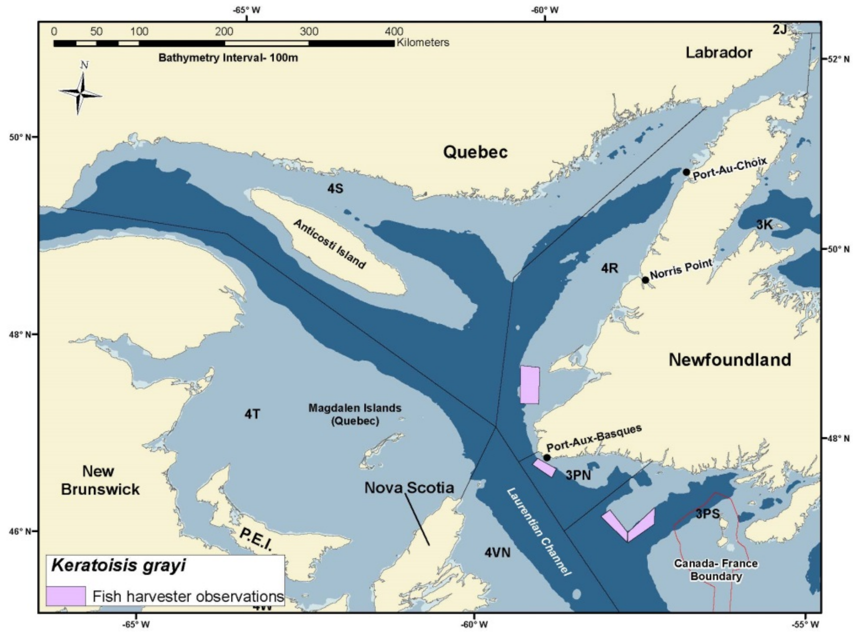

Figure 2.10: Distribution of *Keratoisis grayi* (formerly *Keratoisis ornata*) in the Northern Gulf of St. Lawrence from interviews with fish harvesters

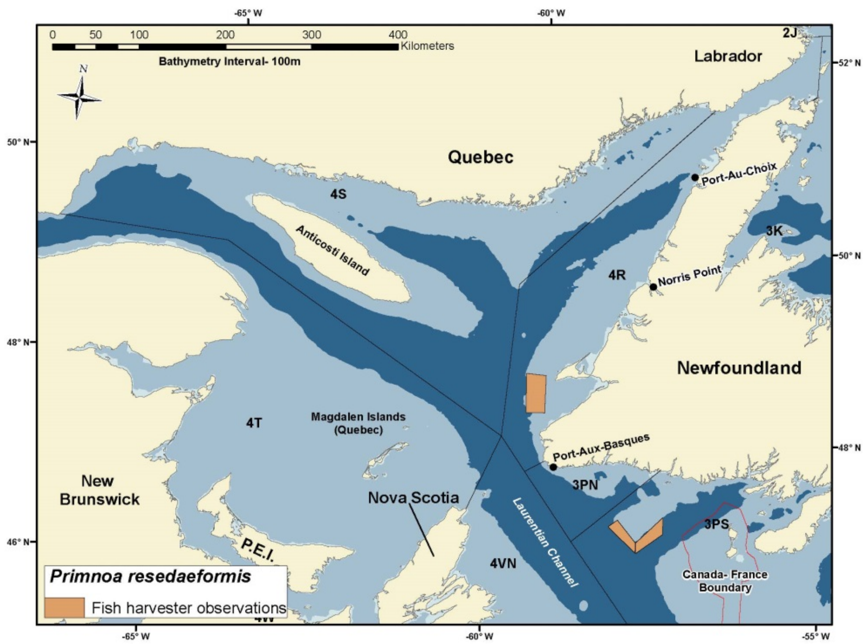

Figure 2.11: Distribution of *Primnoa resedaeformis* in the Northern Gulf of St. Lawrence from interviews with fish harvesters

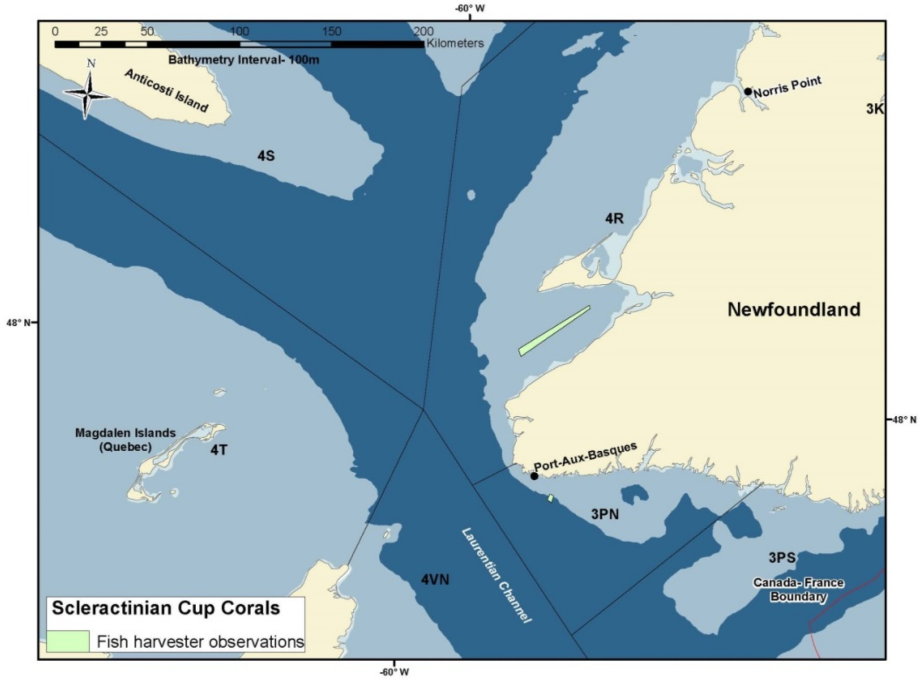

Figure 2.12: Distribution of Scleractinian cup corals in the Northern Gulf of St. Lawrence from interviews with fish harvesters

2.4 DISCUSSION

2.4.1 Summary of coral distribution in the Northern Gulf of St. Lawrence

This study provided the first records for 7 species/groups of deep-sea corals in the Northern Gulf of St. Lawrence. These include *Acanthogorgia armata*, *Primnoa resedaeformis* and Scleractinian cup corals, whose distribution was mapped, and, *Acanella arbuscula*, *Radicipes gracilis*, *Paragorgia arborea* and Antipatharian corals which were reported to occur in the Northern Gulf but the locations of these encounters was unknown.

Nephtheid soft corals, such *Duva florida* and *Gersemia rubiformis*, appear to be the most common group of deep-sea corals to be found in the Northern Gulf of St.

Lawrence. They are found between the depths of 10-500m and have a cosmopolitan distribution in the Northern Gulf, being found in all areas where hard substrates are available for attachment. The occurrence of the nephtheid soft coral *Gersemia rubiformis* was reported at shallower depths (10-30m) in two of the larger bays on the west coast of Newfoundland (Bonne Bay and Bay St. George). Bonne Bay, in particular, has a significant freshwater component in areas where soft corals are found in the East Arm; suggesting *Gersemia rubiformis* may be able to endure estuarine conditions or are located below the freshwater layer in Bonne Bay.

Compared with other areas in Atlantic Canada, nephtheid soft corals are more abundant in the Gulf of St. Lawrence. In Cogswell et al. (2009) neptheid soft coral densities were reported to be highest in the Southern Gulf of St. Lawrence in NAFO division 4T, with most of the sampling effort focused on the Southern Gulf. The results from this study show that neptheids are abundant in the Northern Gulf as well, and in general, there is a higher abundance of nephtheids in the Gulf than on the continental margins of Atlantic Canada.

Sea pens are also common in the Northern Gulf where they are found in abundance in the soft bottoms of the deeper-water Esquiman, Anticosti and Laurentian Channels. While most of their sampling was done in the Southern Gulf (NAFO division 4T), Cogswell et al. (2009) found sea pens to be the most abundant in the Laurentian Channel compared to other areas in the Gulf, mirroring the results of this study. The difference is in this current study, the focus was on the Northern Gulf and it was determined that sea pens are also found in high densities in the other deep-water channels in the Northern Gulf (Esquiman and Anticosti Channels).

Neptheid soft corals and sea pens were also found to be the most common species found along the continental margins of Newfoundland and Labrador (Wareham & Edinger 2007). From DFO trawl survey data, both nephtheid soft corals and sea pens also had the highest reported biomass in the Laurentian Channel; the deepest channel in the Northern Gulf.

The Alcyonacean soft coral *Anthomastus grandiflorus* was reported from both DFO trawl survey records and interviews with fish harvesters. It appears to be common in the Northern Gulf, but its distribution is not as ubiquitous as that for nephtheid soft corals and sea pens. There were no records for *Anthomastus grandiflorus* in the Gulf in Cogswell et al. (2009), with most of their records for this species found in the Gully Marine Protected Area and the *Lophelia pertusa* Coral Conservation Area.

Previous studies by Gass and Willison (2005) and Cogswell et al. (2009) reported observations of *Keratoisis grayi* near Port-Aux-Basques in the Bay St. George area, which were complemented by reports of fish harvesters in this current study of encountering large gorgonians (including *Keratoisis grayi* and *Primnoa resedaeformis*) and solitary cup corals in this same area. Both Cogswell et al. (2009) and this current study have records of Keratoisis grayi in the same area (Bay St. George). Based on our current knowledge, large gorgonian corals, such as Keratoisis grayi, are less abundant in the Gulf, and are generally found in higher abundance, density and diversity in other areas such as the continental slope. Additionally, there was one record of Acanthogorgia armata in the Gulf from previous mapping exercises (Cogswell et al. 2009). This was found in NAFO division 4R, which was also where all observations of Acanthogorgia armata were in this current study.

Scleractinian cup corals were reported to occur in Bay St. George and in one area off Port-Aux-Basques in this current study. Cogswell et al. (2009) had no records of cup corals in the Gulf, and based on limited observations in this current study, it appears cup corals are less abundant here than other areas, such as the continental slope.

Temperature data from DFO Quebec Region show that Bay St. George and areas off Port-Aux-Basques in NAFO division 3Pn have warmer bottom temperatures at shallower depths than other areas in the Northern Gulf (see Figure 2.13). These areas are located on the shelf break where strong currents, suitable bottom temperature and hard substrates provide suitable habitat for large gorgonian corals.

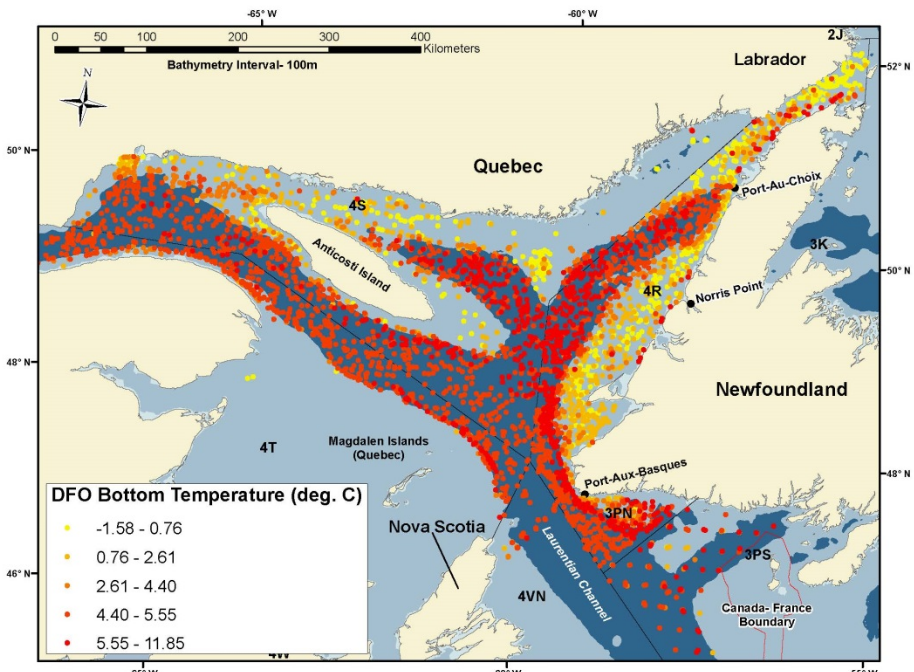

Figure 2.13: Bottom temperature records for the Northern Gulf of St. Lawrence from DFO Quebec Region (Summer 2009)

As mentioned above, the occurrence of seven new species/groups of deep-sea corals, in particular, large gorgonian species were reported during interviews with fish harvesters but were absent from DFO trawl survey data and fisheries observer records. This demonstrates the depth of knowledge fish harvesters have about their fishing grounds and components of local marine ecosystems.

The large gorgonians *Acanthogorgia armata*, *Keratoisis grayi* and *Primnoa resedaeformis* have not been caught in DFO survey trawls in NAFO division 3Pn or anywhere else in the Gulf of St. Lawrence. The areas in which these species are found have been previously sampled by DFO trawl surveys, however, it is possible that these corals are found in rough areas with hard substrate or occur on ledges where is not possible for DFO to sample using the mobile bottom-trawl gear used in their scientific surveys. Survey trawls in steep or rough terrain often target the tops of ridges, in order to maintain depth-constant trawls of standardized length, hence missing the steepest and rockiest terrain in a given area (Wareham & Edinger 2007). In contrast, in the example of NAFO division 3Pn, the fishery for groundfish is exclusively hook and line. Using longlines, fish harvesters in 3Pn are able to fish areas with rougher seafloor than DFO survey trawls.

As shown in figures 2.6, 2.7 and 2.8, the interview data on the distribution of nephtheid soft corals, sea pens, and the soft coral *Anthomastus grandiflorus* complements and enhances what has been previously recorded from DFO survey trawls and fisheries observer data. When conducting interviews with fish harvesters in Nova Scotia and Newfoundland regarding the distribution of deep-sea corals on the continental margins of Atlantic Canada, Gass and Willison (2005) determined that combining three sources of information (DFO survey trawl data, fisheries observer records and interview data) yielded more information than focusing on just one source. A benefit from using multiple sources of data is the overlapping of information from different data sources to help confirm reliability and validity of results (Gass & Willison 2005). In addition, when using multiple sources of data, it is possible that one source can provide unique information on a particular area as well. While the methods used in this current study were similar to those used by Gass (2002) and Gass and Willison (2005), the main difference between the studies is that soft corals and sea pens were considered in this study, while their distributions were not discussed in Gass (2002) and Gass and Willison (2005).

2.4.2 Sources of distributional data

DFO survey trawl data provided 843 records of coral bycatch from a total of 7565 sets between the years 2001-2009. These records were fairly precise in terms of their locations of encounters and provided information on both the presence and absence of corals in trawls (see Figure 2.14) Three species/groups of deep-sea coral were represented in the trawl survey data including two species/groups of soft corals (nephtheids and *Anthomastus grandiflorus*) and sea pens.

Fisheries observer data provided three records of coral bycatch in the Northern Gulf from the years 2001-2008. These three records were all for nephtheid soft corals. Fisheries observer records were presence only data as it was not recorded when coral bycatch was not observed. While there were very limited fisheries observer data for coral bycatch, these records were also fairly precise in their locations of encounters (see Figure 2.14).

The information recorded during interviews with fish harvesters was used to map the general distribution for seven species/groups of corals in the Northern Gulf. The observations of fish harvesters were also presence-only, as all of the areas where they had not encountered corals were not recorded during interviews. While the locations of encounters as reported by harvesters were less precise than the records from DFO survey trawls and fisheries observers, fish harvesters' described the distribution of a greater diversity of species than the other two sources of data (see Figure 2.15). The general distributions of an additional four species/groups missed by DFO trawl surveys and fisheries observers were possible because the information provided by fish harvesters. These included the distributions of the small gorgonian *Acanthogorgia armata*, the large gorgonians *Keratoisis grayi* and *Primnoa resedaeformis* and Scleractinian cup corals.

DFO survey trawl data provided distributional data for three species/groups; fisheries observer records provided records for one group, and one species of large gorgonian (*Keratoisis grayi*) was previously reported to occur in the mouth of Bay St. George by Gass and Willison (2005). In this study, fish harvesters' LEK provided the first records for the occurrence of 7 species/groups of deep-sea coral in the Northern Gulf of St. Lawrence.

Fish harvesters' LEK provided the general distribution for a greater diversity of corals than the other two sources of data (see Figures 2.14 & 2.15). While bycatch records from both DFO survey trawls and fisheries observers were more precise in their locations of encounters, and in taxonomy (identifying to species as opposed to group level), fish harvesters identified coral distributions missed by trawl surveys and fisheries observers. One possible explanation for this is the longer periods of observation for fish harvesters, both in terms of number of years-fished and the number of days on the water each year. Another possible explanation is the removal of deep-sea corals by fisheries, so harvesters later on in their careers may have observed the bycatch of species that are no longer there. One other explanation is that most of the harvesters interviewed here fish in areas that are not covered in regional survey trawls, specifically coastal inshore areas (Neis 2011).

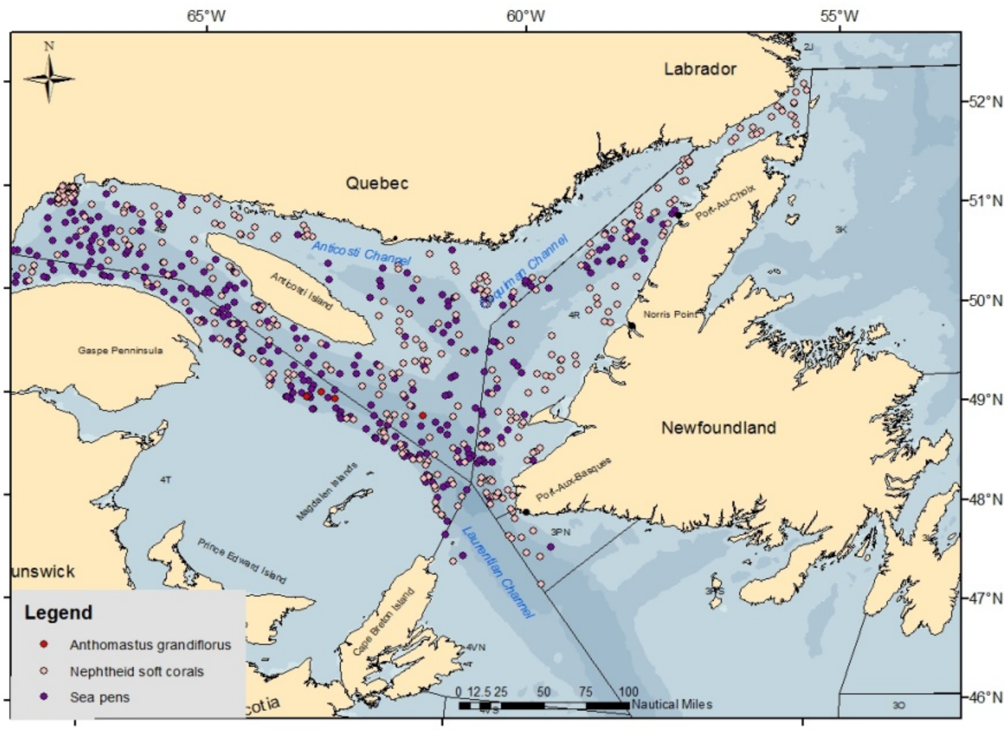

Figure 2.14: Deep-sea coral diversity in the Northern Gulf of St. Lawrence determined from DFO survey trawl and fisheries observer records of coral bycatch

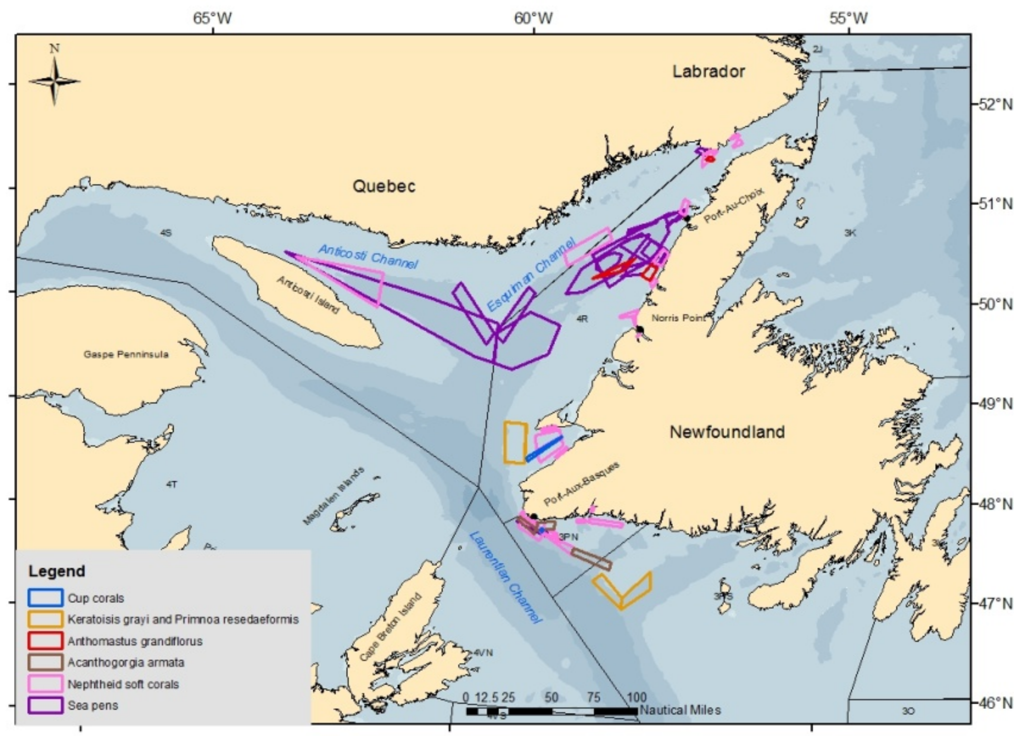

Figure 2.15: Deep-sea coral diversity in the Northern Gulf of St. Lawrence as reported by fish harvesters

2.5 CONCLUSIONS & RECOMMENDATIONS

The Northern Gulf of St. Lawrence appears to have lower coral diversity than surrounding areas in Atlantic Canada (i.e. Gass & Willison 2005, Wareham & Edinger 2007, Cogswell et al. 2009, Wareham 2009). This was not surprising as the Northern Gulf lies on the continental shelf, while the greatest diversity of deep-sea corals in Atlantic Canada has been reported from the continental slope and deeper submarine canyons.

Among the many types of marine protected areas (MPA) are ‘hot spot’ and ‘representative areas’ approaches to conservation. A coral ‘hot spot’ refers to an area with a high density/abundance of corals of either one or many species (Breeze and Fenton

2007). By contrast, a ‘representative areas’ approach seeks to represent all of the major habitat types found within a region, hence, would include a representative sample of the species found within the ecosystem (Fontaine et al. 2015) .

While the hot spot approach has been used to protect deep-sea corals in other areas in Atlantic Canada, a representative areas approach may be the best way to protect deep-sea corals and associated benthic habitat in the Northern Gulf of St. Lawrence.

One area in the Northern Gulf that stands out for its higher coral diversity is Bay St. George. The occurrence of large gorgonian species in the mouth of Bay St. George has been reported in previous studies (Gass & Willison 2005, Cogswell et al. 2009) as well as in this study. At the moment there is no bottom trawling or gillnetting in this area, however, longlines are still able to catch and impact deep-sea corals (Edinger et al. 2007a). Underwater in situ observation, using either a drop camera or remotely operated vehicle (ROV), is recommended.

The geographical area covered by DFO survey trawls was different than that covered by the LEK of fish harvesters. Survey trawls generally exclude coastal waters and fjords, including Bay St. George, which can be covered when using fish harvesters' LEK. Survey trawls in the Northern Gulf did cover areas outside the fishing grounds of the interviewed fish harvesters, mostly in NAFO division 4S. More interviews should be done with fish harvesters in inshore coastal areas, bays and fjords to determine whether corals are present such as was done in Bonne Bay and Bay St. George in this current study. There should also be further interviews with harvesters fishing in 4S.

There were few records of deep-sea coral bycatch collected by the fisheries observer program in the Northern Gulf of St. Lawrence. For example, sea pens have been reported to be common in the Northern Gulf by both DFO survey trawls and fish harvesters, yet there are no records of sea pens in the fisheries observer data. The Northern shrimp fishery has 100% observer coverage (DFO 2009) in areas known to contain sea pens, suggesting that there are no standard requirements regarding the recording of coral bycatch in the current fisheries observer program. We recommend that fisheries observers in the Northern Gulf should receive training in coral identification and be required to record occurrences of incidental coral bycatch. Fisheries observer data has proven to be very useful in determining the distribution of deep-sea corals in the Newfoundland and Labrador region (Wareham & Edinger 2007, Wareham 2009). Along with improvements in the recording/reporting of coral bycatch, we would advise improved communication and cooperation between the fisheries observer program in the Northern Gulf and both DFO and academic researchers.

2.6 ACKNOWLEDGEMENTS

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CHAPTER THREE: DEEP-SEA CORAL BYCATCH IN THE NORTHERN GULF OF ST. LAWRENCE (4RS3Pn): INSIGHTS GAINED FROM INTERVIEWS WITH FISH HARVESTERS

ABSTRACT

The focus of Chapter two was to generate maps showing the distribution of deep-sea corals in the Northern Gulf of St. Lawrence using DFO survey trawl and fisheries observer records of coral bycatch along and the local ecological knowledge (LEK) of Northern Gulf fish harvesters. In Chapter Three, the information recorded during 28 career-history style interviews with Northern Gulf fish harvesters (gillnetters, longliners and shrimp trawlers) on the occurrence of deep-sea coral bycatch in Northern Gulf fisheries is reported. As noted in Chapter Two, fish harvesters interviewed for this study identified eleven species/groups of deep-sea corals that were caught as bycatch in Northern Gulf fisheries. This chapter asks questions about the fishing experience of the harvesters that participated in interviews, particularly about their observations of coral bycatch in Northern Gulf fisheries. Based on their observations, questions on factors they associated with increased rates of bycatch, changes in the amount of coral bycatch observed through their careers, observations on the relationship between deep-sea corals and fish were addressed. Fish harvesters' opinions on the target fisheries and gear types that produce the most coral bycatch are also reported, as well as, their opinions on the importance of deep-sea corals and appropriate conservation measure for their protection in the Northern Gulf. Coral bycatch was observed in eight different fisheries using six different gear types including demersal gillnets and longlines, shrimp trawl, scallop

dredge, Scottish seine and otter trawl. 71.4% of the fish harvesters who participated in this study reported that there has been no change in the amount of deep-sea coral they observed as bycatch throughout the span of their fishing careers. 75% of the fish harvesters interviewed reported that they had observed a relationship between deep-sea coral bycatch and commercial fish species. These species included Atlantic cod (*Gadus morhua*), Atlantic halibut (*Hippoglossus hippoglossus*), Greenland halibut/turbot (*Reinhardtius hippoglossoides*) and Northern shrimp (*Pandalus borealis*). Larger landings were most commonly associated with high sea pen bycatch. All but one harvester interviewed for this study believed that corals are important components of the Northern Gulf marine ecosystem and that they warrant some level of protection, although opinions on appropriate conservation measures differed somewhat among gear sectors.

3.1 INTRODUCTION

3.1.1 Deep-sea corals and deep-sea coral habitats

Deep-sea corals are benthic sessile invertebrates commonly found on the continental margins of Atlantic Canada and worldwide. In Atlantic Canada, they have recently received attention due to an increased awareness of their diversity, abundance and vulnerability to commercial fisheries (Breeze et al. 1997, Gass & Willison 2005, Edinger et al. 2007, Wareham & Edinger 2007, Cogswell et al. 2009, Wareham 2009). Deep-sea corals are particularly vulnerable to bottom fishing due to their longevity and their slow growth and recruitment rates (Roberts et al. 2006, Roberts et al. 2009, Sherwood & Edinger 2009). For example, large gorgonians, such as *Keratoisis grayi* and *Primnoa resedaeformis*, which are found on the continental slopes of Atlantic Canada, can grow to be hundreds of years old (Sherwood & Edinger 2009) and colonies of the Scleractinian reef-forming coral *Lophelia pertusa* can be thousands of years old (Hall-Spencer et al. 2002).

Deep-sea coral habitats are also emerging as systems of ecological (e.g. Krieger & Wing 2002, Buhl-Mortensen and Mortensen 2005) and economic importance (e.g. Foley et al. 2010), raising concern over their rapid destruction (Watling and Norse 1998, Fosså et al. 2002, Roberts et al. 2009). Like shallow-water coral reef systems deep-sea corals provide structurally complex habitats for a variety of marine species (Krieger & Wing 2002, Roberts et. al 2009, Buhl-Mortensen et al. 2010, Watling et al. 2011).

Different species/groups of deep-sea coral provide habitats of varying size and life spans (Roberts et al. 2009). Gorgonians, such as *Primnoa resedaeformis* and *Paragorgia arborea* appear to support fewer species than reef-forming Scleractinians such as *Lophelia pertusa* (Roberts et al. 2009). This is likely because reef-forming corals like *L. pertusa* provide greater surface area and diversity of habitat than gorgonian species (Metaxas & Davis 2005). However, in Atlantic Canada, gorgonian species have been found to grow close together in dense forest-like habitats (Mortensen & Buhl-Mortensen 2004, Gass & Willison 2005, Baker et al. 2012) that support a high diversity of other species (Buhl-Mortensen et al. 2010). Small gorgonians (such as *Acanthogorgia armata*), Alcyonacean soft corals (such as *Gersemia rubiformis*), and sea pens (order Pennatulacea) can also act as habitat for feeding and spawning by other species. Evidence has shown that biogenic structures that reach even a few centimeters into the water column can be utilized by a variety of marine organisms (Buhl-Mortensen et al. 2010, Watling et al. 2011).

While deep-sea coral habitats support fewer species of fish than shallow-water corals (Sale 1991, 2006), recent correlative studies and predictive models have shown increased adult fish density and size in areas containing deep-sea corals compared with areas having no coral (Husebø et al. 2002, Auster 2005). There are facultative relationships between deep-sea corals and fish as both are often found on the continental slope in areas with locally-accelerated currents (Auster 2005, Roberts. et al. 2006, Roberts et al. 2009, Baillon et al. 2012). Many of the studies that have reported a relationship between deep-sea corals and fish have assessed fish populations in areas with large gorgonians, such *Primnoa* spp., and the reef-forming Scleractinian *Lophelia pertusa*. However, recent studies in the Newfoundland and Labrador region have shown evidence for the importance of smaller species/groups of deep-sea coral, such as Alcyonacean soft corals and sea pens (order Pennatulacea) as fish habitat (Edinger et al. 2007b, Baillon et al. 2012, Baillon 2014).

3.1.2 Deep-sea corals in the Northern Gulf of St. Lawrence

The distribution, abundance and diversity of deep-sea corals is now fairly well known for Atlantic Canada as a whole, but less is known about the distribution of deep-sea corals found in the Northern Gulf of St. Lawrence, encompassing NAFO (Northwest Atlantic Fisheries Organization) divisions 4R, 4S and 3Pn (see Figure 3.1), or their bycatch in Northern Gulf fisheries and thus their relationship to the larger ecosystem.

The most important factors determining deep-sea coral distributions are appropriate water temperatures, available substrates, currents and depth. While the greatest diversity of deep-sea corals in Atlantic Canada has been reported from the continental slope (Wareham & Edinger 2007), areas in the Northern Gulf should provide suitable habitat for deep-sea corals. The Northern Gulf of St. Lawrence lies entirely on the continental shelf. A majority of the Northern Gulf is less than 200m deep but there are several deeper-water channels such as the Esquiman, Anticosti and Laurentian Channels which contain water that remains above $0^{o}C$ year-round. Sea pens are common on the continental shelves and margins of Atlantic Canada (Edinger et al. 2007b, Wareham 2009 and Baillon et al. 2012) and require soft, muddy substrates on which to settle. The bottom of the deep channels may provide suitable habitat for sea pens in the Northern Gulf. Furthermore, the sides of these channels have steep slopes that may provide appropriate substrate for corals to colonize.

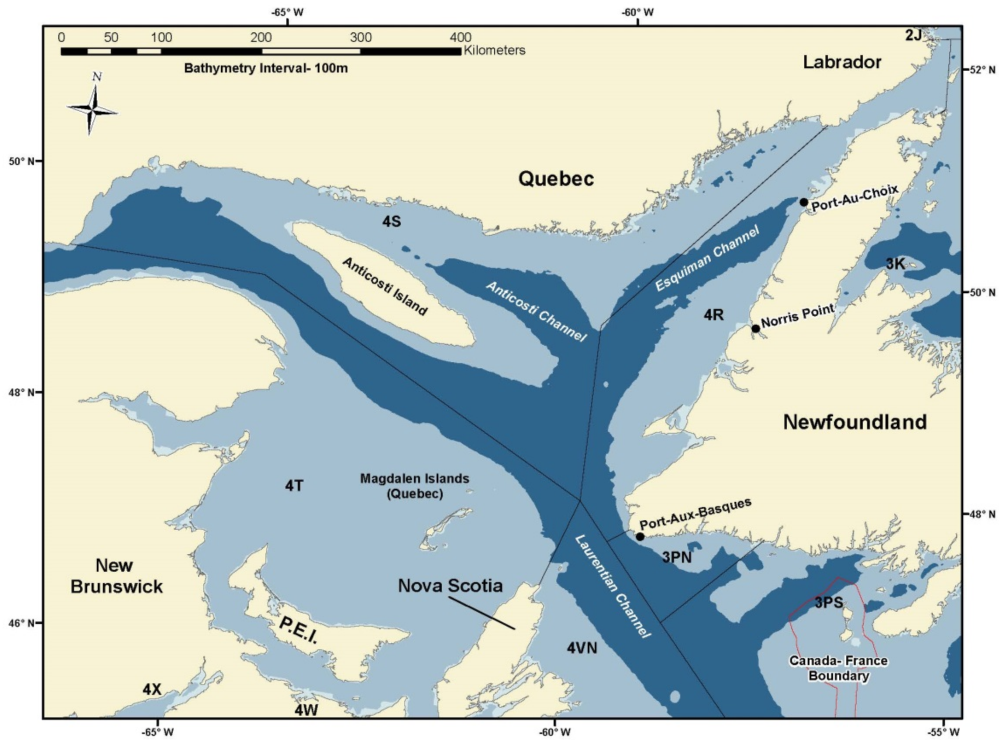

Figure 3.1: Northern Gulf of St. Lawrence (encompassing NAFO divisions 4R, 4S and 3Pn)

3.1.3 Deep-sea coral bycatch

The incidental bycatch of non-target species is a problem worldwide. Many fish stocks have been fished to the point of commercial extinction (Myers & Worm 2003) and an even greater number of non-commercial species are disappearing due to the elimination of habitat and being caught as incidental bycatch in large fisheries (i.e. Dulvy et al. 2005). Following the collapse of shelf fisheries in the mid-twentieth century, the fishing industry has moved into progressively deeper waters resulting in fishing activity on most of the world's continental shelves, slopes and on offshore banks and seamounts (Watling & Norse 1998, Roberts et al. 2009). In the Newfoundland and Labrador region, this movement into deeper waters took place in the 1980's and early 1990's and was associated with the collapse of the cod fishery (*Gadus morhua*)(Sinclair 1985)

Some gear types are considered to be worse than others in terms of their lack of selectivity and their impact on the seafloor (Chuenpagdee et al. 2003, Fuller et al. 2008). However, it is important to look at all gear types that come into contact with the bottom when considering the impacts of fishing on deep-sea coral habitats and on the incidence of deep-sea coral bycatch in commercial fisheries. While bottom trawling has been recognized as the most destructive fishing method, deep-sea coral bycatch has been recorded when fishing using bottom trawl, gillnet and longline gears in Atlantic Canada (Gass & Willison 2005, Edinger et al. 2007b) and elsewhere (Sampaio et al. 2012, Witherall & Coon 2001).

Because deep-sea corals are caught incidentally, information on the association between target and bycatch species is required to assess impacts, as well as information on the gear types and targeting practices. While there has not been any bottom trawling for groundfish in the Northern Gulf since the moratorium on Northern Gulf cod in 1994, many areas of the Gulf, particularly the Esquiman Channel in NAFO division 4R (see Figure 3.1), continue to be trawled heavily for Northern shrimp (*Pandalus borealis*). Shrimp trawlers use an otter trawl outfitted with a Nordmøre grate[2]. While the Nordmøre grate has been successful in decreasing the bycatch of non-target groundfish species, from the point of view of corals landed or discarded from the vessel, this innovation does not reduce the damage exerted by the trawl on the seafloor and thus on corals (Edinger et al. 2007a, Wareham 2010). Further innovations introduced in the 1980`s, such as rock hopper gear, make it possible to fish in areas that were previously too rough to trawl, thereby increasing the trawlable area and thus risk to corals.

Since the moratorium, some harvesters have continued to fish for cod using demersal gillnets and longlines at a reduced temporal and spatial scale from the past. Along with cod, many Northern Gulf harvesters fish for Atlantic halibut (*Hippoglossus hippoglossus*) and Greenland halibut/turbot (*Reinhardtius hippoglossoides*) using the same or similar gear types.

3.1.4 Local ecological knowledge and using qualitative interviews to record fish harvesters' knowledge on deep-sea corals and deep-sea coral bycatch

In the past couple of decades, researchers from both the natural and social sciences have recognized the value of fish harvesters' knowledge for understanding their target species, incidental bycatch and the marine ecosystems in which they fish. The expert knowledge of fish harvesters is a form of local ecological knowledge (LEK),

[2]The Nordmøre grate is an aluminum grid attached to the otter trawls used by shrimp trawlers and is mandatory when fishing for Northern shrimp in the Northern Gulf of St. Lawrence.

which is commonly defined as the knowledge held by a group about their local ecosystem (Olsson & Folke 2001). While the majority of studies using LEK have focused on species that are commercially fished, recent studies provide evidence in support of the use of LEK research methodologies for studying species that are caught as incidental bycatch during commercial fisheries (Carruthers & Neis 2011, Dawe & Neis 2012, Dawe & Schneider 2014), including deep-sea corals. Recent studies using the LEK of fish harvesters on both deep-sea coral distributions and the impacts of fishing on benthic habitats have allowed information not otherwise available to be recorded (Fosså et al. 2002, Gass (2002), Gass & Willison 2005, Sampaio et al. 2012).

In a study on the extent of fishing impacts to *Lophelia pertusa* reefs off Norway, Fosså et al. (2002) relied heavily on information gathered from fish harvesters to determine that 30-50% of the reefs have been damaged or impacted from bottom trawling. Gass and Willison (2005) conducted interviews with fish harvesters to determine the distribution of deep-sea corals in Atlantic Canada. Antipatharian corals were identified during these interviews, providing the first record for the occurrence of this group in Atlantic Canada. Further, deep-sea coral hot spots in Newfoundland and Labrador reported by Edinger et al. (2007a), were first suggested as areas of interest by fish harvesters prior to the study. When looking at deep-sea coral bycatch in the Azores, Sampaio et al. (2012) used the knowledge of fish harvesters to determine that deep-sea corals are commonly caught as bycatch in local longline fisheries. Further, the harvesters were able to confirm which species of coral are most commonly caught as bycatch and helped determine that there has been a decrease in coral bycatch over time in these fishing areas.

3.1.5 Using Local Ecological Knowledge to study fisheries impacts on deep-sea corals in the Northern Gulf of St. Lawrence

Existing scientific records of deep-sea coral bycatch in the Northern Gulf come primarily from DFO groundfish survey trawls and to a lesser extent from fisheries observer records (see Chapter Two). DFO survey trawls use a bottom trawl when doing annual multi-species surveys and all of their records of coral bycatch were while using bottom trawl gear. There is currently no information available on the occurrence of coral bycatch using different gear types in the Northern Gulf. Elsewhere such information was recorded by fisheries observers and reported by fish harvesters in various deep-sea fisheries (i.e. Gass 2002, Gass & Willison 2005). In the Northern Gulf, no current regulations are in place for fisheries observers to record coral bycatch and such information is not currently available.

In this chapter, data from qualitative semi-structured interviews with 28 ‘expert’ fish harvesters will be used to determine in which fisheries there is deep-sea coral bycatch in the Northern Gulf and the gear types used when coral bycatch was observed. This included the bycatch of all species/groups of deep-sea corals including soft corals, sea pens, cup corals, Antipatharians, and both small and large gorgonians. Further, factors identified by the harvesters affecting coral bycatch and changes in the amount of coral bycatch over time will be discussed. The fish harvesters interviewed were considered ‘experts’ in that they had more than 20 years of fishing experience and were referred to by their peers as being particularly knowledgeable about Northern Gulf fisheries (Davis & Wagner 2003).

Using qualitative interviews to access the local ecological knowledge (LEK) of fish harvesters, the first objective was to record the demographics and fishing experience of the fish harvesters who participated in interviews. The second objective was then to determine which species/groups of deep-sea corals occur in the Northern Gulf based on fish harvesters' observations of deep-sea coral bycatch. The third objective was to determine in which fisheries and in association with which gear types the harvesters reported observing coral bycatch and increased rates of coral bycatch. Finally, using fish harvesters' personal observations and experience with coral bycatch, the fourth objective of this study was to record any factors associated with increased rates of coral bycatch, to explore the relationship between fish and areas containing deep-sea corals and to record the opinions of fish harvesters concerning the degradation of deep-sea corals in the Northern Gulf and appropriate measures for their conservation.

3.2 METHODS

3.2.1 Interviews

All data for this chapter come from interviews with fish harvesters. Slight differences in reporting on the interview methods between Chapters Two and Three reflect the different objectives of the two chapters. Interviews took place during November and December 2009 in three communities on the west coast of Newfoundland. These communities were Port au Choix, located on the Northern Peninsula of Newfoundland, Norris Point, located in the Bonne Bay area, and Port-Aux-Basques, located on the southwest tip of Newfoundland (see Figure 3.1). Between the original moratorium on fishing for Northern Gulf cod in 1994 and 2009, fish harvesters have targeted a number of different species using various sized vessels and multiple gear types.

While very few fish harvesters in the Northern Gulf are involved in just one fishery, the main fisheries of the fish harvesters contacted to participate in this study were Atlantic cod (using gillnets and longlines) and Northern shrimp (using bottom trawl). These three communities were chosen so that gillnetters, longliners and shrimp trawlers could all be represented in this study and to access fish harvester LEK about coral distributions along the entire west coast of Newfoundland.

Port au Choix was chosen because it is where the Northern Gulf fleet of shrimp trawlers is based. Norris Point was chosen because it is the location of the Bonne Bay Marine Station (Memorial University of Newfoundland) and because fish harvesters in the Bonne Bay area target a variety of groundfish species including cod and turbot using both longlines and gillnets. Port-Aux-Basques was selected because the fishery for groundfish in NAFO division 3Pn is exclusively hook and line and most of these longliners are based in Port-Aux-Basques and the surrounding areas. Longliners from Port-Aux-Basques also fish Bay St. George, where gorgonian corals were previously reported during interviews with fish harvesters (Gass & Willison 2005).

Contact was made with elected representatives of the FFAW (Fish Food & Allied Workers) who provided us with names of potential interview participants in their constituencies. At the end of each interview, participants were asked if they knew of anyone else in their area who would be knowledgeable about Northern Gulf of St. Lawrence fisheries; in particular, about the incidental bycatch of deep-sea corals. This process, known as snowball sampling (Goodman 1961) is commonly used in the social sciences (Newman 2000) and in research involving the LEK of resource users, including fish harvesters (Neis et al. 1999, Hutchings & Ferguson 2000, Neis & Felt 2000, Murray et al. 2008). Fish harvesters' who were skippers of their own vessels, had more than 20 years of fishing experience and were deemed 'experts' by their peers (Davis & Wagner 2003) were targeted for this study.

Semi-structured interviews were conducted where a fixed list of questions was asked during each interview with room for expansion to elaborate or discuss other topics that may come up during the interview (Patton 1990). The interviews were not audio-recorded in an attempt to make participants more at ease with the interview process and in order to engage interview participants in normal conversation. A research assistant took detailed notes on the interviews while the interviews took place. The DFO identification guide for deep-sea corals in the Newfoundland & Labrador Region (see Appendix A) was used during the interviews along with preserved coral specimens from DFO Newfoundland Region.

During the interviews fish harvesters were asked about their fishing areas in which they had observed coral bycatch. These fishing areas were mapped directly into ArcGIS version 9.3 using a Lenovo tablet laptop by either the harvesters themselves or by the interviewers (see Chapter Two). Areas where no coral bycatch was observed were not recorded. Along with questions about fish harvester demographics (age, education level) and fishing history (years of experience, formal training, status as crew or skipper and vessel size), the following specific questions relevant to this chapter were asked during each interview:

1. Which Northern Gulf fisheries they are currently involved with or have previously participated in?
2. Which gear types have they fished in the Northern Gulf of St. Lawrence?

3. Which species/groups of deep-sea corals have they encountered as bycatch while fishing in the Northern Gulf of St. Lawrence?
4. Are there any factors (environmental or other) that they associate with coral bycatch or increased rates of coral bycatch?
5. In which directed fishery, and with which gear types did they encounter the most coral bycatch?
6. Did they observe any change (increase/decrease) in the amount of deep-sea coral bycatch in the Northern Gulf over time throughout their fishing careers?
7. Are deep-sea corals important, and if so, what conservation measures would be appropriate to protect deep-sea corals in the Northern Gulf of St. Lawrence?
8. What is the relationship (if any) between deep-sea corals and fish (including shrimp)?

For more details on the interview questions, a complete version of the interview schedule used can be found in Appendix B of this thesis. Slight differences between the questions found in the interview schedule and those presented here reflect the evolution of the interview process through the course of the study.

3.2.2 Feedback meetings

Following the interviews, preliminary data analysis and mapping was done using ArcGIS 9.3 (see Chapter Two). Feedback meetings were then held in the same communities in May 2010 in order to present and verify the results and information reported during interviews. All fish harvesters that participated in interviews were contacted for follow-up feedback meetings.

3.3 RESULTS

3.3.1 Interview & feedback meeting participation

51 fish harvesters were contacted for participation in interviews. Roughly 55% of the fish harvesters contacted for this study participated in interviews. All of these individuals were elected representatives of the FFAW or were suggested by their peers. Those who did participate in interviews were experienced fish harvesters who, based on their familiarity with deep-sea corals, provided valuable information on the distribution, abundance and species richness of deep-sea corals in the Northern Gulf of St. Lawrence.

By the time the authors were finished conducting interviews in a given area, the names of other fish harvesters suggested began repeating themselves which suggests that the authors had begun to saturate the sample in that area in that the same names were suggested throughout snowball sampling at the end of interviews

All 28 of the interview participants were contacted again for follow-up feedback meetings. Only 8 of the original 28 (≈29%) participated in feedback meetings.

3.3.2 Fish harvester demographics & fishing experience

All of the fish harvesters interviewed were males between the ages of 34 and 69. The average age was similar amongst gillnetters, longliners and shrimp trawlers at 49-52 years (see Table 3.1). Education levels were similar among the gear sectors with 17 of the 28 participants (≈61%) having completed high school. All the fish harvesters interviewed had received formal training in navigation, safety or both.

The average experience was around 30 years across the three gear sectors (see Table 3.1) with years of experience ranging from 17-53. 26/28 (≈93%) interview participants were skippers of their own vessels, though all had previous or current experience working as crew on other vessels. The remaining two fish harvesters included a retired skipper and a career crew member in a family operation. The gillnetters, on average, used slightly smaller boats than the cod longliners (see Table 3.1). The shrimp trawlers all fished used larger ’65 footers’[3].

Table 3.1: Age, years of experience and vessel size of interviewed Northern Gulf of. St Lawrence fish harvesters

Demographic	**Gillnetters (12)**	**Longliners (10)**	**Shrimp trawlers (6)**	**Total (28)**
Average age (years)	51.2	49	52.8	51
Range of age (years)	45-60	34-69	47-58	34-69
Average fishing experience (years)	32	29.4	31.2	30.9
Range of fishing experience (years)	28-40	17-53	19-44	17-53
Average vessel length (feet)	36.7	41	65	44.3
Range in vessel size (feet)	35-45	35-65	65	35-65

The gillnetters had been involved in more fisheries and were familiar with the use of more gear types than the longliners and shrimp trawlers. Longliners were involved in more fisheries than shrimp trawlers while shrimp trawlers were familiar with more gear types than the longliners. Individual fish harvesters interviewed for this study had been involved with 2-9 fisheries throughout their careers and throughout the year. The average

[3]’65 footer’ is a colloquial term in the fishing industry for the size of a vessel. It should be noted, for regulatory reasons, that these vessels are actually all slightly less than 65 feet in length.

number of fisheries for each harvester was highest for gillnetters (8.4); followed by longliners (5.9) and shrimp trawlers (4.8) (see Table 3.2). As a group, the gillnetters were currently or had previously been involved with the most fisheries (n=21) followed by longliners (n=17) and shrimp trawlers (n=11) (see Table 3.2). The average number of gear types used by harvesters was highest for gillnetters (n=6.3) followed by shrimp trawlers (n=4) and longliners (n=3.5) (see Table 3.3). As a group, the gillnetters were familiar with the most gear-types (n=15) followed by shrimp trawlers (n=9) and longliners (n=7) (see Table 3.3)

Table 3.2: Target-species of interviewed Northern Gulf of St. Lawrence fish harvesters

Target species	**Gillnetters (12)**	**Longliners (10)**	**Shrimp trawlers (6)**	**Total (28)**
Atlantic cod (*Gadus morhua*)	12	10	6	28
Atlantic halibut (*Hippoglossus hippoglossus*)	11	10	2	23
American lobster (*Homarus americanus*)	10	8	2	20
Atlantic herring (*Clupea harengus*)	10	2	1	13
Atlantic mackerel (*Scomber scombrus*)	9	3	1	13
Turbot/Greenland halibut (*Reinhardtius hippoglossoides*)	9	0	4	13
Snow crab (*Chionoecetes opilio*)	7	5	0	12
Lumpfish (*Cyclopterus lumpus*)	6	6	0	12
Witch flounder/grey sole (*Glyptocephalus cynoglossus*)	6	3	1	10
Atlantic capelin (*Mallotus villosus*)	8	1	1	10
Northern shrimp (*Pandalus borealis*)	1	0	6	7
Atlantic redfish/ocean perch (*Sebastes fasciatus*)	1	2	3	6
Sea scallop (*Placopecten magellanicus*)	2	0	2	4
American plaice (*Hippoglossoides platessoides*)	1	2	0	3
Atlantic hake (*Urophycis tenuis*)	0	2	0	2
Atlantic salmon (*Salmo salar*)	1	1	0	2
Seal (*Halichoerusspp.*)	2	0	0	2
Squid (*Loligo pealei*)	1	1	0	2
American eel (*Anguilla rostrata*)	1	0	0	1
Atlantic hagfish (*Myxine glutinosa*)	0	1	0	1
Sea cucumber (*Cucumaria frondosa*)	1	0	0	1
Sea urchin (*Stronglylocentrotus droebachiensis*)	1	0	0	1
Swordfish (*Xipias gladius*)	0	1	0	1
Whelk (*Buccinum undatum*)	1	0	0	1
Wolffish (*Anarhichas spp.*)	0	1	0	1
Total no. fisheries	**21**	**17**	**11**	
Average no. fisheries	**8.4**	**5.9**	**4.8**	
Range of values	**4-14**	**4-8**	**2-8**	

Table 3.3: Gear-types used by interviewed Northern Gulf of St. Lawrence fish harvesters

Gear type	**Gillnetters (12)**	**Longliners (10)**	**Shrimp trawlers (6)**	**Total No. (28)**
Gillnet	12	8	3	23
Longline	11	10	2	23
Lobster pots	11	7	2	20
Crab pots	9	4	0	13
Otter trawl	2	4	6	12
Capelin trap	7	0	1	8
Shrimp trawl	0	0	6	6
Cod trap	5	0	0	5
Purse seine	4	0	1	5
Handline	4	0	1	5
Scallop dredge	2	0	2	4
Pelagic trap (Herring/Mackerel)	4	0	0	4
Rifle (seal)	2	0	0	2
Divers (Sea urchin)	1	0	0	1
Fyke net (Eel)	1	0	0	1
Hagfish trap	0	1	0	1
Pelagic longline	0	1	0	1
Whelk trap	1		0	1
Total no. of gear types used	**15**	**7**	**9**	
Average no. of gear types used	**6.3**	**3.5**	**4**	
Range of values	**3-9**	**2-5**	**2-8**	

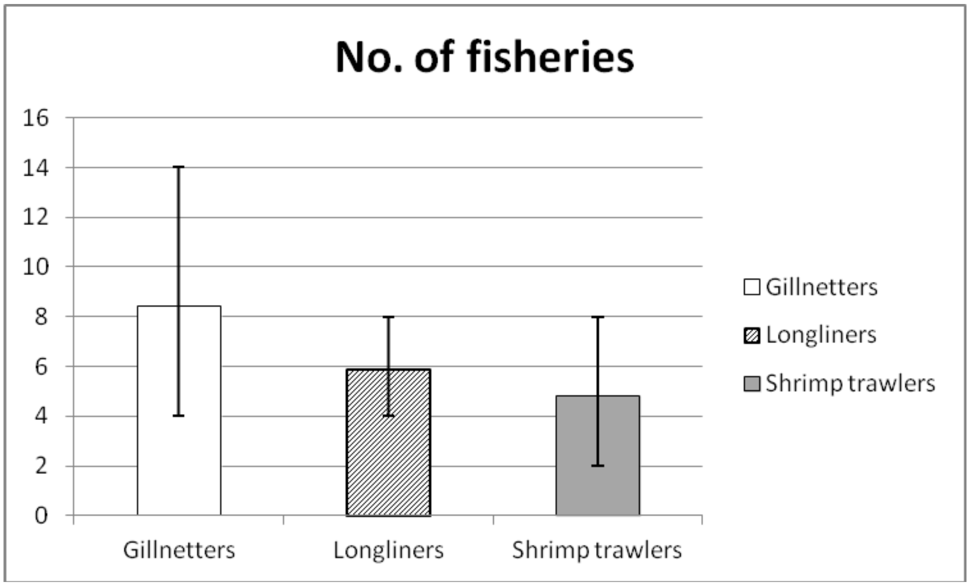

Figure 3.2: Average number and range in the number of fisheries interviewed fish harvesters had participated in throughout their careers

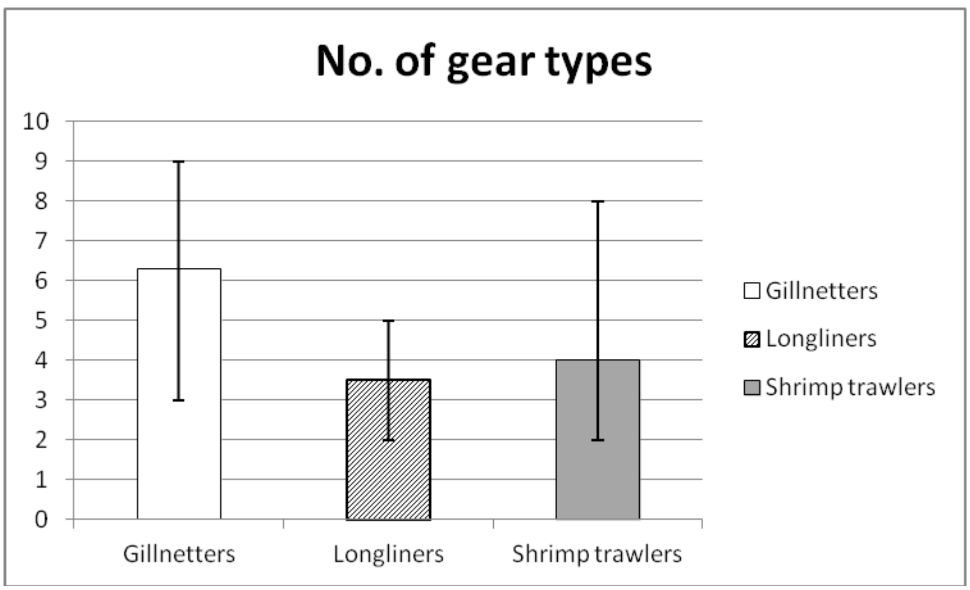

Figure 3.3: Average number and range in the number of gear types used by interviewed fish harvesters throughout their careers

3.3.3 Fish harvester observations of deep-sea coral bycatch in the Northern Gulf of St. Lawrence

3.3.3.1 Species/groups of deep-sea coral observed as coral bycatch

As noted in Chapter Two, eleven species/groups of deep-sea corals were identified by fish harvesters as being caught as bycatch in the Northern Gulf of St. Lawrence (see Table 3.4). These included nephtheid soft corals (such as *Duva florida* and *Gersemia rubiformis*), sea pens (Pennatulaceans), *Anthomastus grandiflorus*, *Acanthogorgia armata*, Scleractinian cup corals, *Radicipes gracilis*, *Primnoa resedaeformis*, *Paragorgia arborea*, *Keratoisis grayi* and Antipatharian black corals.

Nephtheid soft corals (such as *Duva florida* and *Gersemia rubiformis*) were the most common species/group reported, followed by sea pens (Pennatulacea spp.) and *Anthomastus grandiflorus*. These were the same species/groups, in the same order of abundance, recorded by DFO research trawl surveys and fisheries observer records in the Northern Gulf (see Chapter Two). All three of these species/groups appear to have a cosmopolitan distribution throughout the Northern Gulf with nephtheid soft corals and *Anthomastus grandiflorus* being found in areas of varying depths on hard substrates, while sea pens are found in deeper areas with soft bottoms.

Fish harvesters' LEK indicated the distributions of seven species/groups of deep-sea coral including nephtheid soft corals, sea pens, *Anthomastus grandiflorus*, *Acanthogorgia armata*, *Primnoa resedaeformis*, *Keratoisis grayi* and Scleractinian cup corals (see Chapter Two). These maps complemented existing distribution data for nephtheids soft corals, sea pens and *Anthomastus grandiflorus* from DFO research survey trawls and provided distribution data for an additional 4 species not previously known to occur in the Northern Gulf.

While detailed information was not available for the distribution of an additional four species/groups of corals, this study provided the first records for three species/groups' occurrence in the Northern Gulf, *Radicipes gracilis*, *Acanella arbuscula*, and *Paragorgia arborea*, and the second record of Antipatharian corals (Gass & Willison 2005).

Shrimp trawlers, while being the smallest sample size (n=6), identified the greatest number of deep-sea coral species/groups (n=9) using the ID sheets and when asked which species/groups they had previously observed as coral bycatch. While shrimp trawlers reported observing the greatest diversity of coral species/groups, these records are based on a fish harvester's ability to identify familiar coral species and map their distribution; with no actual frequency of encounter number available to truly evaluate the encounters of deep-sea coral bycatch using the gears in question. Both longliners (n=8) and gillnetters (n=8) while able to identify fewer species than the shrimp trawlers still had in depth knowledge of deep-sea corals in their fishing and their bycatch in fisheries.

Table 3.4 Species/groups of deep-sea corals observed as coral bycatch by fish harvesters in the Northern Gulf of St. Lawrence

Species/group	**Gillnetters (12)**	**Longliners (10)**	**Shrimp trawlers (6)**	**Total**
Nephtheid soft corals	11	8	5	24
Sea pens (Pennatulacea spp.)	5	5	6	16
Anthomastus grandiflorus	6	3	2	11
Acanthogorgia armata	4	5	2	11
Cup corals (Scleractinia spp.)	1	3	2	6
Primnoa resedaeformis	1	2	2	5
Radicipes gracilis	0	3	2	5
Keratoisis grayi	0	3	0	3
Acanella arbuscula	2	0	1	3
Paragorgia arborea	0	0	1	1
Antipatharia spp.	1	0	0	1
Total no. species/groups encountered	**8**	**8**	**9**	
Average no. species/groups encountered	**2.6**	**3.2**	**3.8**	
Range of values	**1-6**	**0-8**	**1-8**	

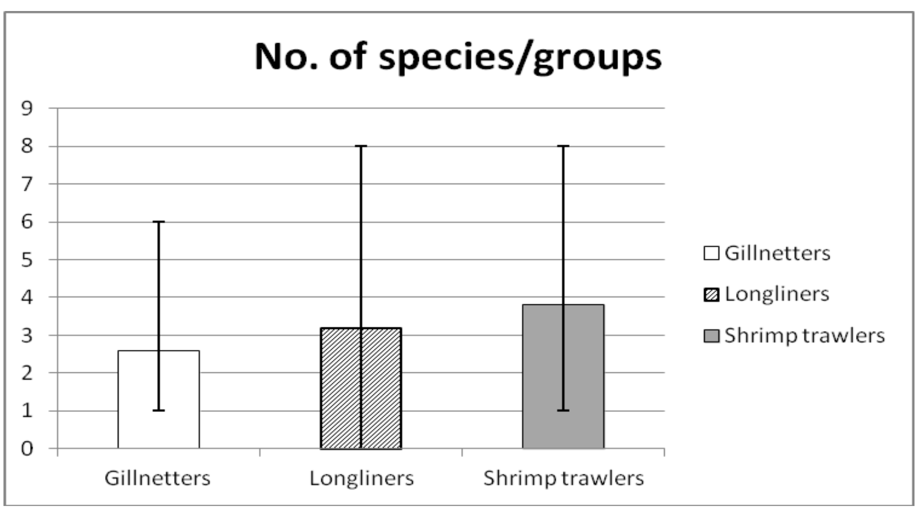

Figure 3.4: Average number and range in the number of deep-sea coral species identified by interviewed fish harvesters

3.3.3.2 Target fisheries and gear types where deep-sea coral bycatch was observed

The bycatch of deep-sea corals was reported from eight fisheries while using six different gear types (see Table 3.5). When fishing for cod, it was observed when using gillnets, longlines and otter trawls. When fishing for halibut it was reported while using longlines. Coral bycatch was also reported when fishing for Northern shrimp using a shrimp trawl both before and after the implementation of the Nordmøre grid. It was also observed when fishing for lumpfish and turbot using gillnets. Coral bycatch was also observed while scallop dredging and when fishing for witch flounder using a Scottish seine. Finally, deep-sea coral bycatch was reported when using an otter trawl to fish for Atlantic redfish. The fisheries most commonly reported to have coral bycatch were cod (using both gillnets and longlines), halibut (longline) and Northern shrimp (shrimp trawl).

Table 3.5: Fisheries and gear types with deep-sea coral bycatch as reported by Northern Gulf of St. Lawrence fish harvesters

Target species	Gear type	Gillnetters (12)	Longliners (10)	Shrimp trawlers	Total (28)
Cod (*Gadus morhua*)	Gillnet	8	3	4	15
	Longline	2	10	0	12
	Otter trawl	1	1	1	3
Halibut (*Hippoglossus hippoglossus*)	Longline	5	8	1	14
Northern shrimp (*Pandalus borealis*)	Shrimp trawl	1	0	6	7
Lumpfish (*Cyclopterus lumpus*)	Gillnet	2	4	0	6
Turbot/Greenland halibut (*Reinhardtius hippoglossoides*)	Gillnet	5	0	1	6
Sea Scallop (*Placopecten magellanicus*)	Scallop dredge	2	0	3	5
Witch flounder/grey sole (*Glyptocephalus cynoglossus*)	Scottish seine	0	3	0	3
	Gillnet	1	0	0	1
Atlantic redfish/ocean perch (*Sebastes fasciatus*)	Otter trawl	0	1	1	2

3.3.3.3 Fish harvester observations on factors contributing to deep-sea coral bycatch or increased rates of bycatch

When asked whether there were any factors that affected whether or not they observed coral bycatch, or increased rates of coral bycatch, the most common answers provided were currents and substrate (see Table 3.6). Most gillnetters and longliners reported current to be the most significant factor while shrimp trawlers reported trawl speed to be the most significant factor. Both gillnets and longlines are fixed gears and are susceptible to shifting off course in areas with high currents while mobile shrimp trawlers reported trawl speed to be the most significant factor. Shrimp trawlers explained how they had increased rates of coral bycatch when they were trawling too slowly as these were the times their gear really dug into the bottom.

Some participants among both gillnetters (n=4) and longliners (n=4) reported substrate to be a factor in the occurrence of coral bycatch. Gillnetters associated coral bycatch with soft bottoms while longliner associated it with hard substrates. The gillnetters, who associated coral with soft bottoms, did so from their experience fishing turbot in deeper offshore areas in the Northern Gulf. The longliners, who associated corals with harder substrates, explained that slope was often a factor as they encountered more corals when fishing over ledges and rock walls. Shrimp trawlers did not mention substrate as a significant factor.

Both mesh size and slope were also reported to be significant factors in affecting the rates of coral bycatch. Both gillnetters and shrimp trawlers explained how using smaller net mesh sizes meant more coral bycatch.

One gillnetter with experience fishing for the sentinel program in the Northern Gulf reported that he saw the most coral bycatch when doing the cod sentinel fishery using a bottom trawl outfitted with rock hopper gear. Rock hopper gear allows areas with rough bottoms, which were previously avoided, to be fished with the consequence being a greater impact on the seafloor. Finally, one shrimp trawler associated deep-sea coral bycatch with increasing depth fished.

Table 3.6: Factors contributing to deep-sea coral bycatch as reported by Northern Gulf of St. Lawrence fish harvesters

Factor	**Gillnetters (12)**	**Longliners (10)**	**Shrimp trawlers (6)**	**Total (28)**
Currents	6	5	0	11
Substrate	4	4	0	8
Mesh size used	2	0	1	3
Slope	2	1	0	3
Trawl speed	0	0	2	2
Use of ‘rock hopper’ gear	1	0	0	1
Depth	0	0	1	1

3.3.3.4 Change in the amount of observed coral bycatch in the Northern Gulf of St. Lawrence

71.4% of the fish harvesters reported no change in the amount of coral bycatch they had observed over time throughout their fishing careers. These included 11/12 gillnetters, 5/10 longliners and 4/6 shrimp trawlers.

One gillnetter reported seeing less coral bycatch than he had in the past, but noted that he fishes less often than he used to. The other five longliners reported increased rates of coral bycatch in NAFO division 3Pn since the Northern Gulf cod moratorium in 1994 when bottom trawling for groundfish in the area ceased. The most common species/group they reported encountering in 3Pn since the moratorium was sea pens and reported seeing them more often since the moratorium. One shrimp trawler reported a decrease in the amount of coral bycatch (specifically sea pens) in 4R since their gear was outfitted with the Nordmøre grate. Finally one shrimp trawler reported a large decrease in the amount of deep-sea coral bycatch over his career, attributing the decrease in bycatch to the effects of bottom trawling in the Northern Gulf for groundfish and shrimp on coral abundance.

Further, one gillnetter interviewed in this study, who fished the deeper-water channels in the Northern Gulf for turbot, suggested that sea pens are able to repopulate an area relatively quickly following disturbance and are shorter-lived than 50 years, as suggested by(Wilson et al. 2002). For example, he stated "*I don't see no difference for the feathers* (sea pens) *in 30 years, they are still coming back the same. The draggers* (shrimp) *are still flattening the zone. I think you have your time periods wrong, it might grow back quicker than you think or there is a lot more out there than you think there is*."

3.3.3.5 Relationship between deep-sea corals and fish in the Northern Gulf of St. Lawrence

When asked about the relationship, if any, between deep-sea corals and fish, the majority of the harvesters interviewed (75%) reported observing a relationship between corals and commercial fish species in the Northern Gulf of St. Lawrence. 50% of the gillnetters, 90% of the longliners and 100% of the shrimp trawlers reported that they believed deep-sea corals provided important habitat for commercial fish species and other species upon which those fish feed.

The gillnetters who reported a relationship associated areas containing deep-sea corals with good fishing grounds for cod and turbot. The longliners, who reported a relationship, believed areas containing deep-sea corals to be good fishing grounds for cod and halibut. They reported that these species were in greater abundance and larger in size when caught in areas containing sea pens. One gillnetter, when referring to fishing in areas containing sea pens, stated: "*If you get that stuff up* (sea pens), *you almost know there is going to be fish there*." Again, when referring to areas with sea pens, one longliner stated: "*We just call it halibut bottoms. When we see it, we tend to get a good catch of halibut. Halibut seem to hang on to that kind of bottom for some reason*."

Shrimp trawlers associated areas containing sea pens with large catches of Northern shrimp. For example, one shrimp trawler stated: "*Only thing that catches my eye is the shrimp grass* (sea pens) *on muddy bottom. Certain areas you find a larger numbers of shrimp when you catch shrimp grass.*"

When discussing the relationship between deep-sea corals and fish, the most common species/group of corals discussed were sea pens. This provides evidence for the importance of sea pen meadows in the Northern Gulf in all three NAFO divisions. In division 4R, soft bottom areas in the Esquiman Channel containing sea pens are considered by harvesters to be good fishing grounds for Northern shrimp, cod and turbot. This was also the case in division 4S, in the Anticosti Channel, where areas containing sea pens were reported to be good fishing grounds for cod and turbot. Finally, in division 3Pn, longliners reported cod and halibut to be more abundant and larger in size when caught in areas known to contain sea pens in the Laurentian Channel. Other recent studies in Atlantic Canada by Edinger et al. (2007b) and Baillon et al. (2012) have also shown an association between sea pens and fish, in particular aggregations of sea pens known as sea pen meadows.

3.3.4 Fish harvester opinions on deep-sea coral bycatch in the Northern Gulf of St. Lawrence

3.3.4.1 Fish harvester opinions on the target-species and gear-types that produce the most deep-sea coral bycatch

When asked their opinions on which fisheries produce the most coral bycatch, the most common responses provided by harvesters were cod (n=9) and halibut (n=5) (see Table 3.7). The majority of gillnetters (n=8) did not think target species had anything to do with it and that using gillnets with smaller mesh sizes (for cod and lumpfish) increased bycatch. For example, one gillnetter stated: "*I don't think the fishery has anything to do with it. It's the net, not the fish. It doesn't matter if I'm fishing for cod or lumpfish, it's net, not one fishery over the other*."

The gillnetters explained that smaller mesh sizes are used to fish for cod and that smaller gillnet mesh sizes increased the amount of coral brought up as bycatch. Longliners explained how, when fishing for cod, there are more hooks on the line than when fishing for halibut, and, that these hooks are smaller circle hooks. Smaller hooks and circle hooks increased the amount of coral bycatch they observed**.** While many longliners fishing for cod and halibut on the same grounds, differences in coral bycatch still came down to gear type and to the number and size of hooks used. For example, one longliner stated: "*You see more with the cod fishery. You have more hooks, you're using more gear and smaller hooks. The smaller hooks hook the stalk better* (referring to sea pens). *Halibut you got a hook every three fathoms, cod fish you got one every fathom*."

In the opinion of half of the shrimp trawlers interviewed (n=3), the scallop fishery is the fishery that produces the most coral bycatch. They explained that the gear used, the scallop dredge, is extremely heavy and believe it is indiscriminate in what it brings up. While cod gillnetters and longliners both named their main fisheries (cod and halibut) as those in which they saw the most coral bycatch, shrimp trawlers did not mention the Northern shrimp fishery when asked their opinion about the fisheries that produce the most coral bycatch.

When asked their opinions on which gear types produced the most coral bycatch, the most common responses provided by harvesters were gillnet (n=14) and otter trawl (n=13) (see Table 3.8). Most gillnetters and longliners believed otter trawl and shrimp trawl to be the most destructive gear type used, however, both reported that they observed the most coral bycatch when employing their main gear type, be it gillnet or longline. For example, one gillnetter answered: "*The most coral I've seen is in gillnets. Otter trawlers,* *seiners, gillnets, any kind of gear that drags or scrapes over the bottom. Just common sense will tell you that, right*?"

Shrimp trawlers named both scallop dredge and gillnets as the gears that produce the most coral bycatch. Shrimp trawlers reported that recent gear modifications they introduced, such as the Nordmøre grate and rock hopper gears, decreased their fishing impacts and consequently reduced coral bycatch. Shrimp trawlers did not report their own gear type to produce any amount of coral bycatch. For example, one shrimp trawler stated: "*Scallop's gotta catch everything that's down there. Me I got balls* (referring to roller gear)*It don't hit hard, even the doors, they are just floating. You know it when you go* (trawl) *too slow*."

Table 3.7: Fish harvester opinions on the fisheries that produce the most deep-sea coral bycatch

Target species	Gillnetters (12)	Longliners (10)	Shrimp trawlers (6)	Total (28)
Cod	2	7	0	9
Halibut	1	4	0	5
Scallop	1	0	3	4
Lumpfish	2	0	0	2
Turbot	1	0	0	1

Table 3.8: Fish harvester opinions on the gear types that produce the most deep-sea coral bycatch

Gear type	Gillnetters (12)	Longliners (10)	Shrimp trawlers (6)	Total (28)
Gillnet	7	2	5	14
Otter trawl	7	5	1	13
Scallop dredge	2	0	3	5
Longline	0	4	0	4
Shrimp trawl	4	0	0	4

3.3.4.2 Fish harvester opinions on the importance of deep-sea corals

When asked why they thought deep-sea corals were important, all of the fish harvesters interviewed reported that they believed deep-sea corals to be important components of the Northern Gulf of St. Lawrence ecosystem. When asked why, the most common answer provided (n=13) was that they provide important feeding, spawning and aggregating areas for various commercial fish species including cod, halibut, Northern shrimp and turbot (see Table 3.9). Eight fish harvesters recognized an intrinsic value of deep-sea corals but were not able to provide explanations as to their role in marine ecosystems. Seven fish harvesters believed deep-sea corals to be important because they provide habitat for species of non-commercial fish and invertebrates upon which the commercially fished species may feed but were unsure about a direct relationship between deeps-sea corals and commercial fish species.

Table 3.9: Importance and value of deep-sea corals as reported by Northern Gulf of St. Lawrence fish harvesters

Reason given	Gillnetters (12)	Longliners (10)	Shrimp trawlers (6)	Total (28)
Habitat for commercial fish species	2	8	2	12
Intrinsic value	4	1	3	8
Habitat for other species (fish and invertebrates)	5	1	1	7

3.3.4.3 Conservation measures for protecting deep-sea corals in the Northern Gulf of St. Lawrence

When asked what conservation measures would be appropriate for protecting deep-sea corals in the Northern Gulf of St. Lawrence, all but one fish harvester believed corals should be awarded some level of protection where significant concentrations were encountered. When asked what conservation measures are appropriate for protecting deep-sea corals in the Northern Gulf, the most common answers were gear restrictions in areas containing significant concentrations of corals (n=16) followed by closing areas containing significant concentrations of corals to fishing altogether (n=12) (see Table 3.9). 58.3% of the gillnetters and 90% of the longliners reported that they believed gear restrictions to be the best way to protect corals in the Northern Gulf. These gillnetters believed that there should be no bottom trawling of any kind in the Northern Gulf while longliners believed that both gillnetting and bottom trawling should be banned. 41.7% of the gillnetters, 50% of the longliners and 33% of the shrimp trawlers believed that the best way to protect corals is to create area closures when coral hot spots are encountered.

16.7% of gillnetters and 16.7% of shrimp trawlers suggested protection through self-regulated ‘move on’ policies when significant concentrations of corals are encountered. 16.7% of shrimp trawlers believed that there should be gear modifications, such as the Nordmøre grate, that are designed to reduce deep-sea coral rather than groundfish bycatch. Further, 16.7% of shrimp trawlers believed that reducing the frequency of fishing was the best way to protect corals giving the example of seasonal fisheries and fishing multiple grounds. The one harvester who didn’t think deep-sea corals should be protected was a gillnetter who fished for turbot in the deeper water channels in the Northern Gulf where sea pens were abundant. While reporting that areas containing sea pens were the best fishing grounds for turbot, he believed that sea pens were abundant in the Gulf and that they have relatively fast growth rates and are able to repopulate an area relatively quickly following disturbance.

Table 3.10: Conservation measures suggested by fish harvesters for the protection of deep-sea corals in the Northern Gulf of St. Lawrence

Conservation measures	**Gillnetters (12)**	**Longliners (10)**	**Shrimp trawlers (6)**	**Total (28)**
Gear restrictions	7	9	0	16
Area closures (coral hot spots)	5	5	2	12
Avoidance of areas containing corals	2	0	1	3
Gear modifications	0	0	1	1
Reduced frequency of fishing	0	0	1	1

3.4 DISCUSSION

3.4.1 Interview methods

The main goal of this study was to use both existing records of coral bycatch and fish harvesters' LEK of coral bycatch to determine the distribution of deep-sea corals in the Northern Gulf of St. Lawrence. DFO groundfish survey trawl and fisheries observer records have been used to map coral distributions on the continental margins of Atlantic Canada including Newfoundland and Labrador (Gass & Willison 2005, Wareham and Edinger 2007, Wareham 2009).

The methods used in this study were similar to those of Gass (2002) and Gass & Willison (2005) in that the same three sources of information were used to map deep-sea coral distributions in Atlantic Canada; DFO survey trawl and fisheries observer records of coral bycatch and the LEK of fish harvesters.. In Gass (2002) and Gass and Willison (2005) semi-structured interviews were conducted with fish harvesters involved in multiple fisheries that used various gear types and similar questions regarding coral bycatch, changes in the amount of coral bycatch and opinions on conservation were addressed. Along with distributional data (see Chapter Two), questions on fisheries and gear types with observed coral bycatch, changes in the amount of observed coral bycatch, the association between deep-sea corals and fish as well as fish harvester opinions on protecting corals were also addressed in this current chapter.

Here, recent reviews of the LEK literature by Davis & Wagner (2003) and Davis & Ruddle (2010), which suggest needed improvements in LEK research, are used to evaluate the methods used in this study to record the LEK of fish harvesters. First there is a need to properly identify 'experts' when recruiting interview participants. For this study, the elected representatives of the FFAW (Fish Food & Allied Workers) in our study areas were contacted and asked to suggest harvesters in their areas who were later on in their fishing careers and were particularly knowledgeable about the Northern Gulf ecosystem and fisheries. Further, snowball sampling (Goodman 1961) was used to recruit other participants in our study areas. All but one harvester interviewed for this study were skippers of their own vessels and the average number of years of experience among the three gear sectors (gillnet, longline and shrimp trawl) was 30.9 years. The methods used in this current study were effective in identifying experts as shown by the diversity of coral species/groups identified by fish harvesters and by their in-depth knowledge of deep-sea corals drawing from their first-hand observations of coral bycatch in Northern Gulf fisheries.

There were limitations however due to time constraints and because not all harvesters that we contacted participated in interviews. Further, some fish harvesters may be unwilling to participate or share their knowledge if the research will likely lead to increased regulations and if fish harvesters have no control or say about the use of their knowledge (Silver & Campbell 2005, Hall et al. 2007, St. Martin & Hall-Arber 2008, Hartley & Robertson 2009).

It is well documented in the LEK literature that there are obvious pragmatic and political motivations to underestimate bycatch levels (Hall et al. 2007, Palmer & Wadley 2007, Carruthers & Neis 2011). The Newfoundland fishing industry is a complex socio-political landscape resulting from mandatory technological changes in fishing gears and the depletion of marine resources over the past few decades (Palmer & Wadley 2007). Therefore, when conducting this type of research, it is important to be aware that certain fish harvesters may provide answers that are mediated by potential consequences for their livelihoods of the outcome of the research. For example, the shrimp trawlers may have been hesitant to name their own gear because of the controversial nature of bottom trawling or, it could be that the Nordmøre grate, while not reducing the amount of impact to the seafloor and thus deep-sea corals has decreased the amount of coral bycatch brought up in the gear or, thirdly, the amount actually observed on the sorting deck. To answer this question we would need systematic research comparing coral bycatch levels observed with and without the grate.

Both reviews also emphasize the need for systematic research designs and detailed reporting of the methods used to conduct LEK research. This design of this study was based on the previous study by Gass (2002) on corals in Atlantic Canada, lending itself to comparison with this and future studies that use similar methodologies. In both studies, the same three sources of data were used to determine deep-sea coral distributions including DFO survey trawl and fisheries observer records of coral bycatch and the LEK of fish harvesters. When recruiting participants for interviews, non-random sampling was used in both studies, in order to target harvesters who were skippers of their own vessels, were later on in their fishing careers and deemed ‘experts’ by their peers (Davis & Wagner 2003). Both studies used snowball sampling to recruit interview participants. Along with snowball sampling, Gass (2002) used other means of recruiting participants by contacting harvesters whose names were obtained from various fishing organizations. In this current study, elected individuals in the FFAW were contacted and asked to suggest harvesters in their constituencies who were skippers of their own vessels, had more than 20 years of experience and had experience fishing for multiple target species using various gear types.

There is also a need to make LEK research transparent and open to public scrutiny (Davis & Ruddle 2010). This can be accomplished by, again, using systematic research designs and providing detailed accounts of the methods used. This study was designed to allow transparency into the methods we used and the data we generated. Participation in this study was voluntary and interview participants were made aware of the potential risks involved in participating in this study as required by the Tri-council Policy Statement on Ethical Conduct for Research Involving Humans (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, and Social Sciences and Humanities Research Council of Canada (2010) (see Appendix B). Further, the results of this study were presented to fish harvesters in feedback meetings prior to publication.

3.4.2 Distinguishing observations from opinions in LEK data.

It is also important to distinguish between observations and opinions while still recognizing the value of both. Observations come from direct first-hand experience. By contrast, opinions, while often drawing on first-hand knowledge and experience; also include the personal views and beliefs of the individual being interviewed. Opinions can be shaped by a range of factors including observations, information gleaned from the media, and from discussions with others.

For example, when recording the LEK of fish harvesters on three species of wolffish (*Anarhichas* spp.) in the Northern Gulf of St. Lawrence currently listed under Canada's Species at Risk Act (SARA) (Dawe & Neis 2012) asked questions based on both the observations and opinions of the harvesters. The abundance and distribution of wolffish populations in the Northern Gulf were based on the first-hand observations and experiences with wolffish bycatch in other fisheries, while questions on the listing of these species and other marine fishes under SARA as well as on current conservation measures used in their fishing areas were opinion based. The use of questions based on both observations and opinions allowed the reporting of important information concerning wolffish populations as well as the attitudes and views of fish harvesters on the current listing of these species under SARA and the effectiveness of current conservation measures.

In this current study on deep-sea corals, questions based on both the observations and opinions of fish harvesters were asked during interviews. Observation-based questions drew on their experience with deep-sea corals as bycatch in their respective fisheries while opinion based questions drew on their beliefs about the impacts of different gear types on deep-sea corals as well as their views on the importance of deep-sea corals and appropriate measures for their conservation in the Northern Gulf.

One of the criticisms of studies using LEK is that researchers do not distinguish between the informants' observations and their theories about these observations (i.e. Palmer & Wadley 2007, Hill et al. 2010, Wiber et al. 2012), so it is important to make this distinction clear as both observations and opinions can provide important information but are different forms of knowledge. Fish harvesters are knowledgeable about their target species and the areas in which they fish, as well as, have opinions about their own fishing practices and those of others who fish the same waters (Wiber et al. 2012). For these reasons, it is important to know the difference between direct experience and opinion as both, through the form of LEK, can be valuable when trying to answer complex social-ecological problems (Perry et al. 2010, Neis et al. 2011, Perry et al. 2011, Ommer et al. 2012) but are inherently different.

One way to improve the methods used in future studies would be to include probes for key questions into the interview schedule. This means asking questions such as "What makes you think this?" or "Why or why not?" in response to the answers given for questions that may be open to interpretation. For example, in this current study, four fish harvesters reported having experience using scallop dredge gear but when asked for their opinions (based on experience) about the gear types that produced most coral bycatch, five harvesters reported scallop dredge. Using probing questions in further LEK research will help researchers further differentiate between observations and opinions.

3.4.3 Precision and accuracy of LEK observations.

Because scientific data and fish harvesters' LEK differ in spatial scale, there are difficulties combining both forms of knowledge (Dawe & Schneider 2014, Usher 2000, Sáenz-Arroyo et al. 2005). When using scientific records and the LEK of fish harvesters there are differences geographical precision among the different sources of data. While less precise, fish harvesters' LEK can be considered consilient (Dawe & Schneider 2014) with other more precise sources of distributional data in that both sources of data can be consistent in showing the same patterns of distribution. Further, where observations diverge, the use of multiple sources and forms of data can allow information from one source to be evaluated and included in assessments. When determining deep-sea coral distributions in Atlantic Canada, Gass (2002) show that using three sources of data can increase the validity when there is concurrence among the sources of data, and allows the recording of information not available if using only one source.

When determining the distribution of three species of wolffish (*Anarhichadidae* sp.) in the Northern Gulf of St. Lawrence, information on wolffish bycatch from scientific stock assessments and the LEK of fish harvesters were used (Dawe 2010, Dawe & Schneider 2014). To map distributions based on the LEK data, polygons were used to represent the fishing areas of the harvesters they interviewed where wolffish bycatch was observed. Composite maps were then made showing area covered by interviews in mostly shallower, coastal areas, where all of the observations of multiple harvesters were represented by polygons showing all fishing areas where wolffish bycatch was observed. Stock assessment records of wolffish distributions were also included in these composite maps. These were the same methods used in Chapter Two to map coral distributions in the Northern Gulf. When determining deep-sea coral distributions in Atlantic Canada, the observations of fish harvesters were also mapped using polygons (Gass 2002, Gass & Willison 2005) and composite maps showed the number of observations in each area as well as the fishing areas where coral bycatch was encountered.

While the LEK of fish harvesters is less geographically precise in terms of locations of encounters, it is still important to include when assessing the distributions of coral in a given area. For example, when determining deep-sea coral distributions in Chapter Two, DFO survey trawl and fisheries observer bycatch records were more geographically precise than fish harvesters' LEK, but missed the distribution of four species/groups of coral.

3.4.4 Summary of deep-sea coral bycatch in the Northern Gulf of St. Lawrence

Eleven species/groups of deep-sea coral were observed as bycatch by fish harvesters in the Northern Gulf including two species/groups of soft coral, sea pens, cup corals, Antipatharians and both small and large gorgonians. Coral bycatch was observed while fishing for eight different species including six species of groundfish and two species of invertebrates. While fishing for these species, fish harvesters reported coral bycatch while using six different gear types.

The most common species/groups reported to be caught as bycatch were neptheid soft corals and sea pens. These are also the most common species/groups reported from the continental margins of Newfoundland and Labrador (Wareham & Edinger 2007, Wareham 2009). 85.71% of the harvesters interviewed for this study reported catching nephtheids throughout the Gulf and at varying depths and found them attached to hard substrates of varying size. 57.1% of harvesters reported sea pen bycatch in the deeper water areas in the Northern Gulf that have soft bottoms, especially in the Esquiman, Anticosti and Laurentian Channels. Fish harvesters reported the highest diversity of corals in NAFO division 3Pn and in Bay St. George in 4R. Nephtheids and sea pens were also the most common species/groups reported from continental margins of Newfoundland and Labrador (Edinger et al. 2007a, Wareham & Edinger 2007).

Based on the results of this study, coral diversity is lower in the Northern Gulf of St. Lawrence than in other regions in Atlantic Canada (i.e. Wareham and Edinger 2007, Cogswell et al. 2009, Wareham 2009). The Northern Gulf of St. Lawrence lies entirely on the continental shelf which may explain why the Northern Gulf has lower diversity as there is less suitable habitat for colonization. While there is a lower coral diversity than in other areas, 11 species/groups of deep-sea coral were reported to occur in the Northern Gulf by fish harvesters in this study, who reported the highest diversity of corals in the Northern Gulf in Bay St. George in NAFO division 4R and in areas of deep-water near Port-Aux-Basques in 3Pn. There also appears to be a particularly high abundance of sea pens in the Northern Gulf of St. Lawrence particularly in the deep-water channels.

Seventy-five percent of the harvesters interviewed for this study also reported an association between commercial species and sea pen bycatch. Gillnetters interviewed for this study reported larger catches of both cod and turbot in areas in 4R and 4S that are abundant in sea pens. The longliners associated larger landings of both cod and halibut with sea pen bycatch in 3Pn. Finally, the shrimp trawlers reported larger landing of Northern shrimp when high levels of sea pen bycatch were observed, particularly in the Esquiman Channel in 4R. Other recent studies in the Newfoundland and Labrador region have also shown evidence for the importance of sea pens and sea pen meadows as habitat for fish (Edinger et al. 2007b, Buhl-Mortensen et al. 2010, Baillon et al. 2012, Baillon 2014), which suggests that more studies are needed on the ecological importance and life history of sea pens in Atlantic Canada, and elsewhere (Krieger 1993, Auster & Langton 1999).

Deep-sea coral bycatch was observed while fishing for eight different target species using 6 different gear types in this current study. In a similar study by Gass (2002) fish harvesters in Atlantic Canada reported observing coral bycatch when fishing for seven different target species using three different gear types. In both Gass (2002) and this current study, coral bycatch was observed when fishing for Atlantic redfish, witch flounder/grey sole, Atlantic halibut, Atlantic cod and turbot/Greenland halibut. In Gass

(2002), the fisheries with the most observed coral bycatch were reported to be turbot, halibut and cod. In this current study, it was these same three fisheries along with Northern shrimp that were reported to have the most observed coral bycatch by fish harvesters.

3.5 CONCLUSIONS & RECOMMENDATIONS

All of the fish harvesters in this study believed deep-sea corals to be important parts of the Northern Gulf marine ecosystem and it is clear that fish harvesters' believe that deep-sea corals provide important habitat for other fish and invertebrate species including commercial species in the Northern Gulf. When asked about appropriate conservation measures for protecting deep-sea corals in the Northern Gulf, answers were different among the gear sectors. Involving fish harvesters in fisheries research can increase their trust in the greater research process and can increase the likelihood of compliance with management decisions (Kaplan & McCay 2004, Chuenpagdee & Jentoft 2007, Wiber et al. (2009).

Results from this current study, and others in Atlantic Canada and elsewhere, show the value of including fish harvesters and their knowledge throughout the whole research process. Recent literature suggests that the LEK of fish harvesters can be useful in both data-rich and data-poor contexts (Boudreau & Worm 2010, Hill et al. 2010, Wiber et al. 2012) and increase the capacity of all stakeholders in making appropriate management decisions (Kaplan & McCay 2004, Wiber et al. 2009).

In the example of deep-sea corals, fish harvesters can be included in on-going research both in identifying species and recording data on their distribution. This can be accomplished by training willing harvesters in basic coral identification and having them record the exact locations where deep-sea coral bycatch is encountered. A similar approach was used to train fisheries observers in other areas in Atlantic Canada, and was extremely useful in determining coral distributions (Gass & Willison 2005, Wareham & Edinger 2007).

Results from this study also show that there is a need for local field studies in Bay St. George (NAFO division 4R) and in the deeper-water areas off Port-Aux-Basques (NAFO division 3Pn) on the sides of the Laurentian Channel. These are where the highest diversity of corals in the Northern Gulf was reported. Soft corals, sea pens, cup corals and both small and large gorgonians were reported to occur in these areas and exploration using either remotely-operated vehicle (ROV) or drop-video would allow the distribution of these species to be mapped with more precision and to reveal their true extent.

This study provides further evidence in an already growing body of literature (i.e. Baillon et al. 2012) that suggests sea pens provide habitat for commercially-fished species. There is limited information available regarding the growth rates and longevity of sea pens (Langton et al. 1990, Wilson et al. 2002, Neves et al. 2013a,b) and the observations of fish harvesters in this current study identify the need for further research on the life history of sea pens.

The planned marine protected area (MPA) in the Laurentian Channel (NAFO division 3Ps) was designed primarily to protect high concentrations of sea pens. While studies such as this show the importance of sea pens and that they should be protected, the small and large gorgonian species reported in the current study to occur on the sides of the Laurentian Channel do not fall within the boundaries of this MPA. There should be further investigation into the occurrence of these species and into their importance to commercial species. These, along with existing data on sea pens, should be included in the future when considering marine protected areas and other conservation measures in the Northern Gulf of St. Lawrence.

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CHAPTER FOUR: CONCLUSIONS & RECOMMENDATIONS

4.1 Summary of deep-sea coral distributions in the Northern Gulf of St. Lawrence

For this project, existing records of coral bycatch along with the local ecological knowledge (LEK) of 'expert' fish harvesters with 20 years or more of fishing experience were used to determine deep-sea coral distributions in the Northern Gulf of St. Lawrence. DFO survey trawl records of coral bycatch along with limited fisheries observer records provided the location of encounters for two species/groups of soft corals (nephtheids and *Anthomastus grandiflorus*) as well as for sea pens (order Pennatulacea). Further, through the use of qualitative interviews with fish harvesters, the distribution of an additional four species/groups was mapped. These included the small gorgonian *Acanthogorgia armata*, the large gorgonians *Keratoisis grayi* and *Primnoa resedaeformis,* as well as Scleractinian cup corals. An additional four species/groups were identified and reported to occur in the Northern Gulf by fish harvesters but the general location of encounters for these species/groups were not known. These included the large gorgonian *Paragorgia arborea*, Antipatharian corals and the small gorgonians *Acanella arbuscula* and *Radicipes gracilis.* This suggests that, while they occur in the Northern Gulf, they are less widely-distributed than the species whose distributions were mapped in this study.

Nephtheid soft corals, such as *Gersemia rubiformis* and *Duva florida*, and sea pens are the most common species/groups of coral to occur in the Northern Gulf. Nephtheids are widely distributed in the Northern Gulf wherever hard substrates are available. They also occur at varying depths in the Northern Gulf and are found as shallow as 10m in some areas of the Northern Gulf including Bonne Bay on the west coast of Newfoundland. Sea pens are also commonly-distributed in the Northern Gulf with the highest abundance and concentrations being reported from the soft bottoms of the deep-water channels found in the Northern Gulf including the Anticosti, Esquiman and Laurentian Channels. Harvester observations and DFO survey trawl data indicate that sea pens are particularly abundant in an area in the Esquiman Channel near Port-Au-Choix that shrimp trawlers refer to as 'The Hole'.

The soft coral *Anthomastus grandiflorus* was found on hard substrates in the Laurentian Channel as well as one area in the Esquiman Channel, near Daniel's Harbour on the west coast of Newfoundland. *Anthomastus grandiflorus* is less widely-distributed than nephtheid soft corals. The small gorgonian *Acanthogorgia armata*, found in areas with hard substrates, was reported to occur mostly in the deep-water off Port-Aux-Basques on the sides of the Laurentian Channel and in one area on the side of the Esquiman Channel, also near Daniel's Harbour.

The large gorgonian *Keratoisis grayi*, which was previously reported to occur in the mouth of Bay St. George by fish harvesters in Gass & Willison (2005), was also identified by fish harvesters in this current study. Along with the mouth of Bay St. George, harvesters also reported that *Keratoisis grayi* occurs on the sides of the Laurentian Channel in the deeper-water areas off Port-Aux-Basques in 3Pn. *Primnoa resedaeformis*, another large gorgonian, was reported to occur in both the mouth of Bay St. George and in some of the same areas as *Keratoisis grayi* on the sides of the Laurentian Channel in 3Pn.

Scleractinian cup corals can are found on both hard and soft substrates depending on the species, however, cup corals were not identified to the species level in this study.

In this study, cup corals were reported to occur in Bay St. George, as well as, in one area near Port-Aux-Basques in 3Pn by fish harvesters.

The Northern Gulf appears to have a lower coral diversity than other areas in Atlantic Canada including the continental margins of Newfoundland and Labrador. The Northern Gulf lies on the continental shelf while the highest diversity of corals in Atlantic Canada has been reported from the continental slope and deep submarine canyons (Gass & Willison 2005, Wareham & Edinger 2007a, Cogswell et al. 2009, Wareham 2009, Baker et al. 2012). Despite having a lower diversity than other areas, eleven species of soft corals, sea pens, small and large gorgonians, cup corals and Antipatharian corals were reported to occur in the Northern Gulf from the three sources of information used in this study. The highest diversity of corals in the Northern Gulf was reported from Bay St. George, in 4R and in deep-water areas in 3Pn near Port-Aux-Basques.

4.2 Summary of fish harvesters` observations on deep-sea coral bycatch in Northern Gulf of St. Lawrence commercial fisheries

Deep-sea coral bycatch was observed by Northern Gulf fish harvesters while fishing for eight different target species using six different gear types. While fishing for Atlantic cod (*Gadus morhua*) coral bycatch was observed while fishing using otter trawl, gillnets and longlines. It was observed when fishing for Atlantic halibut (*Hippoglossus hippoglossus*) using longlines and for Greenland halibut/turbot (*Reinhardtius hippoglossoides*) while using gillnets. Shrimp trawlers also reported seeing coral bycatch when fishing for Northern shrimp (*Pandalus borealis*) while using a shrimp trawl. Coral bycatch, particularly sea pen bycatch, was observed while shrimp trawling both before and after the implementation of the Nordmøre grid. Coral bycatch was also observed when fishing for lumpfish (*Cyclopterus lumpus*) using gillnets and when fishing for Atlantic redfish/ocean perch (*Sebastes fasciatus*) when using an otter trawl. Coral bycatch was also observed when fishing for sea scallops (*Placopecten magellanicus*) using a scallop dredge. Finally coral was observed when fishing for Witch flounder/grey sole (*Glyptocephalus cynoglossus*) when using both a Scottish seine and gillnets.

While most of the fish harvesters interviewed for this study were involved in shallow and deep-water pot fisheries, such as that for snow crab (*Chionocetes opilio*), and in pelagic fisheries for Atlantic herring (*Clupea harengus*) and Atlantic mackerel (*Scombur scombrus*), no coral bycatch was observed in these fisheries. The bycatch of nephtheid soft corals and the small gorgonian *Acanella arbuscula* in snow crab gear was reported previously to occur in other areas of Newfoundland such as the northeast Newfoundland and Labrador slope (Edinger et al. 2007a). It is possible that corals were not observed because of the shallower depths fished in the Northern Gulf.

The total number of species/groups of coral observed as bycatch was similar amongst harvesters in the three main gear sectors with both gillnetters and longliners identifying eight species/groups and shrimp trawlers identifying nine. Although shrimp trawlers were the least sampled group of fish harvesters (n=6), shrimp trawlers identified the greatest diversity of species/groups of coral.

4.3 The role of LEK and fish harvesters in conservation efforts for cold-water corals

In addition to providing data on coral distributions and bycatch occurrences, fish harvesters' opinions about approaches to conservation are important. Most fish harvesters interviewed in this study favored gear restrictions and effort limits over area closures (see section 3.3.4.3). By contrast, marine conservation NGOs (Non-Governmental

Organizations) and DFO have focused much of their effort on increasing the coverage of marine protected areas, particularly for long-lived sessile species like corals and sponges. To be successful, conservation efforts need to have the willing participation of fish harvesters and will probably require a combination of permanent fishery closures and restrictions on fishing activity directed by fish harvesters. Participatory research with fish harvesters will be crucial in finding solutions.

4.4 Conclusions

DFO survey trawl data provided distributional data for three species/groups, fisheries observer records provided records for one group, and one species of large gorgonian (*Keratoisis grayi*) had been previously reported to occur in the mouth of Bay St. George by fish harvesters (Gass and Willison 2005). Fish harvesters' LEK provided the first records for the occurrence of 7 species/groups of deep-sea coral in the Northern Gulf of St. Lawrence. The greatest diversity of corals was also reported from the interviews with fish harvesters, where eleven species/groups of deep-sea corals were identified and reported to occur in the Northern Gulf.

While bycatch records from both DFO survey trawls and fisheries observers were more precise in their locations of encounters, and in taxonomy (identifying to species as opposed to group level), fish harvesters identified coral distributions missed by trawl surveys and fisheries observers. One possible explanation for this is the longer periods of observation for fish harvesters, both in terms of number of years-fished and the number of days on the water each year. One another explanation is that harvesters fish in habitats and areas that are not covered in survey trawls, specifically steep rocky ledges and coastal inshore areas.

Harvesters in all three gear sectors interviewed for this study (gillnetters, longliners and shrimp trawlers) associated high levels of sea pen bycatch with larger landings of commercial species. Shrimp trawlers reported the largest catches of Northern shrimp when seeing sea pen bycatch in NAFO division 4R in the Esquiman Channel. Gillnetters reported larger catches of both cod and turbot in areas containing sea pens in areas in 4R in the Esquiman Channel and in 4S in the Anticosti Channel. Longliners in 3Pn reported larger catches of both cod and halibut in areas abundant in sea pens. There were harvesters in all three gear sectors that reported that they sometimes targeted areas known to contain sea pens because they associated sea pens with larger landings and larger sized fish in the cases of cod and halibut. These firsthand observations of fish harvesters provide new evidence for the importance of sea pens as habitat for commercial fish/invertebrate species in the Northern Gulf.

4.5 Recommendations

Following the work of Berkes (1999) and others, there has been a call among those who research fish harvesters' knowledge to better integrate LEK into fisheries policy and management (Felt 2010, Neis & Felt 2000, Wiber et al. 2012). Co-operative research and co-management approaches can and should be used to increase transparency and accountability of the greater research process (Kaplan & McCay 2004, Chuenpagdee & Jentoft 2007). In the past, failures in the communication process have led to adversarial relationships and tensions among fish harvesters, scientists and managers that can hinder progress towards the proper management of marine resources and ecosystems (Kaplan & McCay 2004).

Fish harvesters should be included in the whole research process when doing fisheries research as both scientific methods and LEK have been found to be complementary and can give researchers a better understanding of both the species being studied and the habitats in which they live. As shown by the in-depth knowledge of deep-sea coral bycatch of fish harvesters in this current study, harvesters possess detailed knowledge about ecosystem relationships, changes over time and the impacts of commercial fisheries (Maurstad et al. 2007, Wiber et al. 2012) including impacts on deep-sea corals (i.e. Witherall & Coon 2001).

Including fish harvesters in future studies of deep-sea corals in the Northern Gulf can be accomplished by training willing harvesters in basic coral identification and having them record the exact locations where deep-sea coral bycatch is encountered. A similar approach was used to train fisheries observers in other areas in Atlantic Canada, and was extremely useful in determining coral distributions (Gass & Willison 2005, Wareham & Edinger 2007). Information from fish harvesters in this current study were derived from their observations of coral bycatch throughout the span of their fishing careers. Recording the location of encounters could produce real-time data on their occurrence as bycatch in Northern Gulf fisheries, as well as, create more distributional data for these species/groups in the Northern Gulf.

The limited Quebec fisheries observer records of coral bycatch, as opposed to records from Newfoundland region fisheries observers, suggests that the fisheries observer program for the Northern Gulf is not effective in identifying corals in bycatch. Fisheries observers from the Quebec region should be trained in basic coral identification and it should be mandatory to report coral bycatch including species/group encountered and the specific locations of encounters. Similar training and reporting requirements were introduced in the Newfoundland region in 2004, and proved highly effective within two years (Wareham et al. 2007). Fisheries observer records of coral bycatch have been extremely useful in efforts to map the distribution of corals on the continental margins of Newfoundland and Labrador (Gass & Willison 2005).

There is a need for local field studies in Bay St. George (NAFO division 4R) and in the deeper-water areas off Port-Aux-Basques (NAFO division 3Pn) on the sides of the Laurentian Channel (see Figure 4.4). These are where the highest diversity of corals in the Northern Gulf was reported. Soft corals, sea pens, cup corals and both small and large gorgonians were reported to occur in these areas and exploration using either remotely-operated vehicle (ROV) or drop-video would allow the distribution of these species to be mapped with more precision and to reveal their true extent.

This study would not have been possible without the use all available sources of information, including the LEK of Northern Gulf fish harvesters. Fish harvester observations and records of coral bycatch should both be used to when doing comprehensive studies on deep-sea corals and their distributions in a given area. We should continue to involve fish harvesters in deep-sea coral research, whether through organizations such as the FFAW (Fish Food & Allied Workers) or by making direct contact with fish harvesters.

Sea pens were reported to provide habitat for a variety of commercial species in this current study. This study provides further evidence in an already growing body of literature (Edinger et al. 2007b, Buhl-Mortensen et al. 2010, Baillon et al. 2012, Baillon 2014) that suggests sea pens provide habitat for commercially-fished species The planned marine protected area (MPA) in the Laurentian Channel (NAFO division 3Ps) was designed primarily for sea pens. While studies such as this show the importance of sea pens, and that they should be protected, the small and large gorgonian species reported to occur on the sides of the Laurentian Channel in this current study do not fall within the boundaries of this MPA. There should be further investigation into the occurrence of these species in the Laurentian Channel, including further interviews with fish harvesters and these, along with existing data on sea pens, should be included when considering MPAs in the Northern Gulf of St. Lawrence.

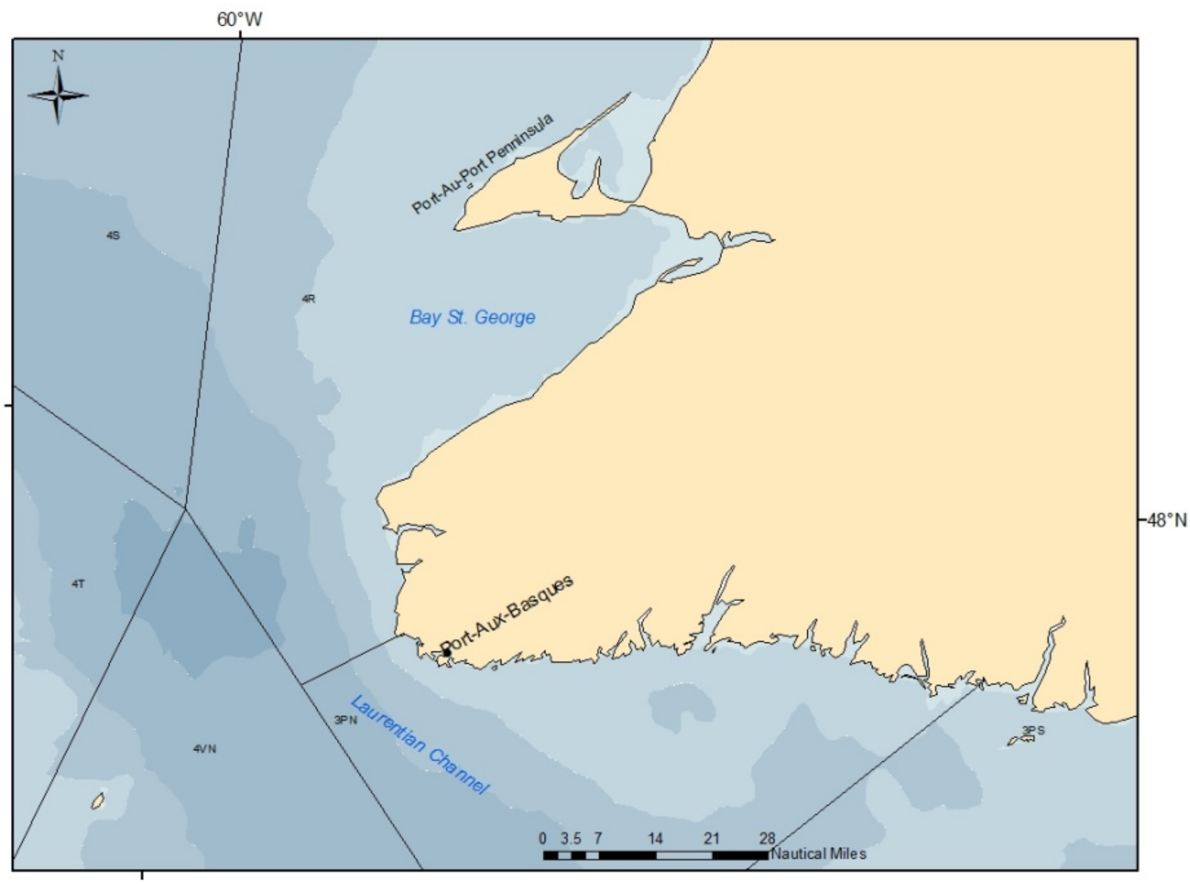

Figure 4.1: Bay St. George (NAFO division 4R) and deep-water areas near Port-Aux-Basques (NAFO division 3Pn) near the Laurentian Channel

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APPENDIX A: Identification guide to deep-sea corals off Newfoundland, Labrador and Baffin Island, Canada

Identification Guide to Deep-Sea Corals off Newfoundland, Labrador, and Baffin Island, Canada

This guide is designed as a user-friendly field tool for aiding fishers, technicians, and fisheries observers on how to identify deep-sea corals at sea. The guide provides a brief introduction on corals and terminology, followed by pictures, *latin* and common names (a.k.a.), numeric codes, and key characteristics of each species that may be encountered.

Collection Protocol:

Any persons wishing to submit a coral sample must ensure that the sample is placed in a plastic bag with a label, sealed, and frozen as soon as possible. Labels can consist of a small piece of paper placed within a bag, and must have the species name, the four digit NL ID code, position (latitude and longitude), depth, and date of capture of the sample, written in pencil only. For large samples, if freezer space is available keep the whole colony. If no freezer space is available, record the total weight, and cut a small subsample (~5 cm in length) from the top and bottom of the sample. It is important not to guess the species, instead all unknown samples are to be coded as **'8900' UNKNOWN** and submitted. Samples can be forward to:

Vonda E. Wareham, Northwest Atlantic Fisheries Centre, 80 East White Hills Road., St. John's, NL A1C 5X1 Canada.
Tel. 709-772-2804 or 709-690-9477; Fax. 709-772-5666; Email. waremamv@dfo-mpo.gc.ca

Introduction:

Thirty deep-sea coral species have been documented off Newfoundland (NAFO divisions 3KLMNOP), Labrador (NAFO divisions 2GHJ), and Baffin Island (NAFO divisions 0AB). Corals are widely-distributed along the edge and slope of the continental shelf, scattered in patches extending from Baffin Basin, to the Grand Banks of Newfoundland, and Flemish Cap. Corals, as discussed here, are deep cold-water species that differ from tropical corals by depth, temperature, and physiology (functions). They are sessile (immobile) animals that live in benthic (bottom) environments and can occupy all types of substrates. They come in many shapes and sizes from small solitary animals (< 1 cm in height) to large colonies (> 2 m in height). An individual refers to one animal called a 'polyp'. A 'colony' refers to many animals or polyps living together on a single structure. Those structures can form large deep-sea reefs comprised of living and dead corals (i.e. *Lophelia pertusa*) or form branching tree-like colonies (i.e. *Paragorgia arborea*). Corals feed on suspended particulate matter (detritus and zooplankton) transported by ocean currents. Each polyp extends and retracts tentacles that capture food floating in the water column. Currents not only supply food but also remove fine sediments that can choke the polyp and inhibit feeding processes. In general, corals are usually found in areas with strong currents, at depths below 200 m, and approximately 4-6 °C water temperature.

Corals are animals from the Phyllum Cnidaria; Class Anthozoa. In this region, there are four orders from three subclasses: 1. Octocorallia - Orders Alcyonacea and Pennatulacea; 2. Hexacoralli - Order Scleractinia; 3. Ceriantipatharia - Order Antipatharia. Each order will be discussed briefly followed by the associated species.

1. Order Alcyonacea are part of the subclass Octocorallia; easily identified by eight tentacles on each polyp. Alcyonaceans are divided into three groups: the 'hard' gorgonians (consolidated axis), the 'spongy' gorgonians (unconsolidated axis), and the 'soft' corals.

The gorgonians (Page 2 and 3), are the largest (< 2 m in height) and are among the longest-lived with some species reaching 100s of years in age. Gorgonians are subdivided into two groups based on the composition of the skeleton; six species with a 'hard' consolidated axis and two species with a 'spongy' unconsolidated axis.

The soft corals (Page 4) are small (< 10 cm) and have no 'true' skeleton. They maintain their upright shape by hydrostatic pressure. Colonies usually resemble vegetables, like cauliflower, broccoli and mushrooms. There are at least four species of

2. Order Scleractinia (Page 5), the 'true' hard corals, can form small (< 10 cm in height) solitary cup-shaped animals or large deep sea reefs constructed of living and dead animals (kms in length x 30 m in height). *Lophelia pertusa* is the only known reef-forming species in the Northwest Atlantic, and it is only documented on the Scotian Shelf. There are four species of solitary cup corals found in the region.

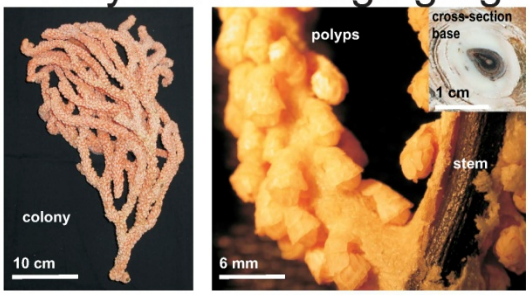
3. Order Antipatharia (Page 6), the 'black-wire' corals consist of thin black axis with pointy-tipped branches. They can grow extremely slow (< 1 mm per year) and are long-lived with some colonies reaching 100s of years in age. They vary in size (10-80 cm in height), and there are at least two deep water (+1000 m) antipatharians species found in the region.

4. Order Pennatulacea (Page 6), the 'sea pens', are also part of the subclass Octocorallia. Some sea pens resemble old-fashion quill pens, while others can look like clubs or umbrellas, but all have a single main fleshy stem with a calcareous internal axis. Sea pens are the most abundant group and vary in size (10-150 cm in height). They are also the most diverse group with 11 species found in the region.

Deep-Sea Coral On Line Resources:

Deep sea Coral of Newfoundland and Labrador: http://www.mun.ca/geog/research/habitat_mapping/mapping_dist_of_corals.php
Corals in the Maritimes: http://www.mar.dfo-mpo.gc.ca/oceans/e/ocmd/coral/coral-e.html
Centre for Marine Biodiversity: http://marinebiodiversity.ca/en/home.html

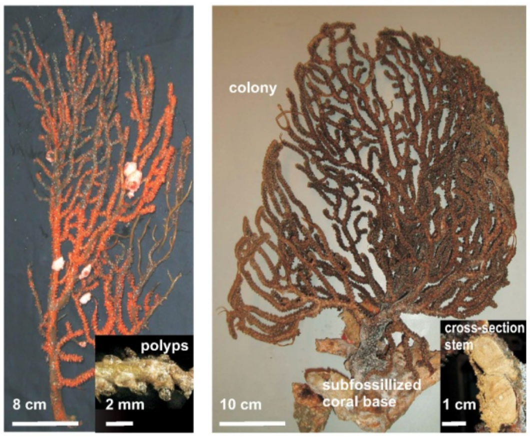
Alcyonacea: large gorgonians (consolidated axis)



Primnoa resedaeformis (NL ID code 8902)

a.k.a. **popcorn coral**

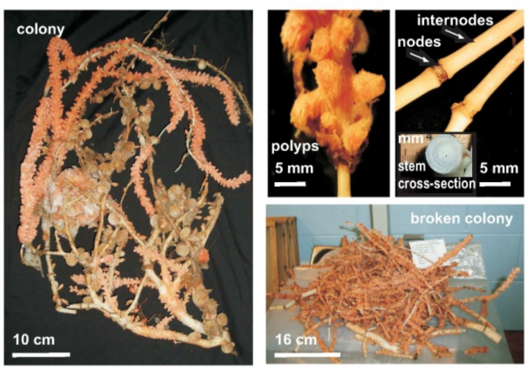
Found on the edge and slope between 160-1150 m, with significant concentrations on northeast Saglek Bank, off northern Labrador. Colonies are large densely branching (dichotomy = branches divide by 2) trees that can reach heights up to 1 m. The skeleton is hard and constructed of two alternating compounds: calcium carbonate (white) and gorgonin (dark-brown). The base is usually larger and more calcified for support, especially in older colonies. Downward facing polyps are armoured with scales and can be pink, or salmon in colour. Colonies are usually found attached to hard substrates like cobbles, boulders, and rock outcrops.



Paramuricea placomus *Paramuricea grandis* (NL ID code 8912)

a.k.a. **black coral**

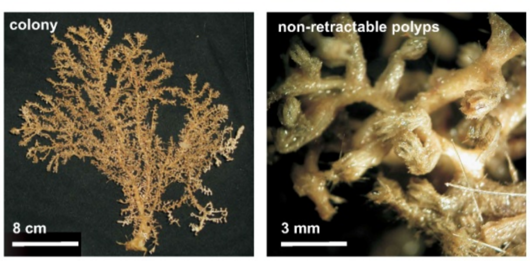
Found on the edge and slope between 150-1500 m, but mostly in deep waters. There are two species, which are difficult to distinguish. Colonies are large irregular branching tree-like fans that can reach up to 80 cm in height. The skeleton is tough but flexible, and is covered with delicate tissue that can peel off if severely damaged. Bare skeletons that lack tissue are a dark olive-green colour. Polyps are round and laterally compressed to stem. When alive, the colony is a vibrant reddish-orange or salmon colour but quickly turns black once removed from the ocean floor (see photos). The base, if intact, is usually large and fused to hard substrates like cobbles, boulders, and other hard subfossilized corals (see photo).



Keratoisis ornata (NL ID code 8906)

a.k.a. **gold-banded or bamboo coral**

Found locally on the southwest Grand Banks between 200-1100 m. Colonies are large irregular branching trees, usually in one plane, that can reach heights up to 1.5 m. Branches and stem tend to be thicker towards the base of the colony. The skeleton is comprised of two parts; small flexible nodes (dark golden-brown proteinaceous joints), and large rigid internodes (hard white calcareous sections that are separated by nodes). The skeleton can be densely or sparsely covered with delicate pink or salmon-coloured polyps that radiate out in all directions from the skeleton. Base of colony is fused to hard substrates like cobbles, boulders, rock outcrops, and other hard subfossilized corals. Warning: tissue and polyps are covered in needle-like sclerites, small microscopic spines, that can act like splinters.



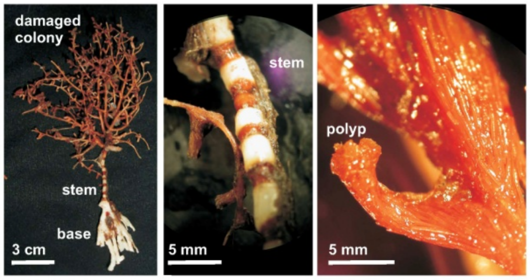
Acanthogorgia armata (NL ID code 8907)

a.k.a. **bushy coral**

Found on the edge and slope between 170-1400 m. Colonies are profusely branching bush-like trees that can reach heights up to 50 cm. The skeleton is tough, flexible, and fibrous. Colonies are densely covered in polyps that are a uniform colour, gray or tan. Polyps are non-retractable and have a long neck zone with crown-like tips. Base of colony is fused to hard substrates like cobbles, boulders, rock outcrops, and other hard corals.

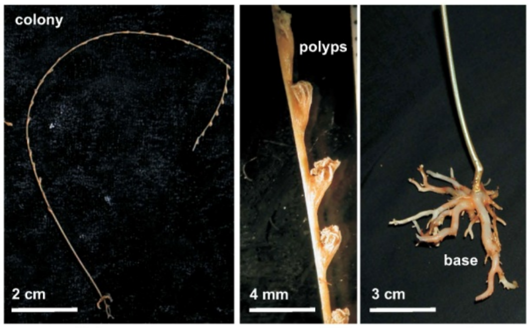
2

Alcyonacea: small gorgonians (consolidated axis)



Acanella arbuscula **(NL ID code 8909)**

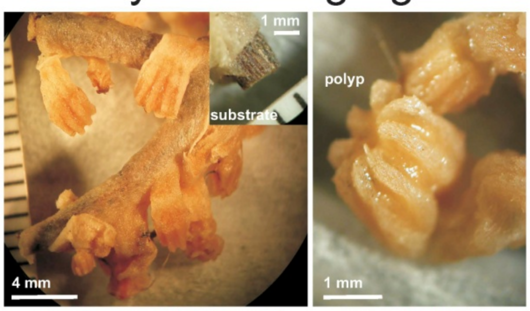
a.k.a. **little tree coral, or bonsai coral**
Found on the edge and slope between 150-1400 m. Can occur as 'fields' with multiple colonies being captured per tow. Colonies are delicate miniature trees that are rigid and are usually < 30 cm in height. Skeleton is easily damaged and consists of dense branches tapering to a single banded stem; white and amber in colour. The calcified base is a large root-like holdfast that is imbedded in soft substrates. Tissue and polyps are amber in colour. Polyps are positioned at 45°angles to branches. Note: Can cause allergy-like symptoms (i.e. sneezing, watery eyes, and itching).



Radicipes gracilis **(NL ID code 8910)**

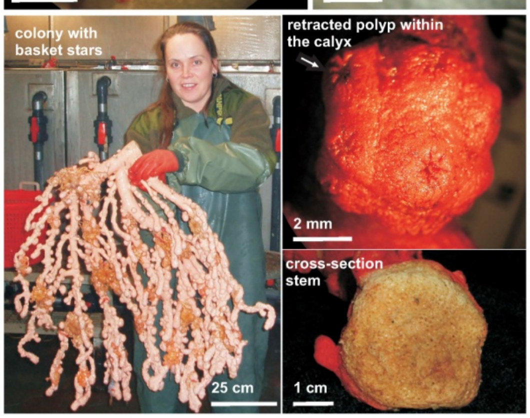
a.k.a. **sea whip**
Found on the edge and slope between 400-1500 m. An individual colony consists of a slender spirally twisted axis with no branching, and is usually < 40 cm in height. Polyps are light orange with a pinkish hue, and are evenly spaced on one side of the stem at oblique angles. The stem has an iridescent shimmer. The colony is supported by a white calcified root-like base that is imbedded in soft substrates like muds or clays.

Alcyonacea: gorgonians (no consolidated axis)



Anthothela grandiflora **(NL ID code 8915)**

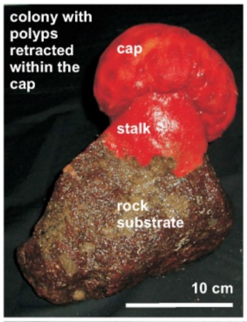
a.k.a. **no common name**
Found on the edge and slope between 500-1000 m, off northern Labrador with one occurrence off Northeast Newfoundland Shelf. Most likely found elsewhere but, due to its small size, it's probably overlooked or lost through the mesh of a net. Colonies are fragile and small usually < 5 cm in height, with no intact samples submitted. Colonies have no true skeleton; instead they encrust shells, stones and other stick-like substrates. Polyps are elongated and can be yellow or buff in colour. More information on morphology is needed and any additional samples are welcomed.

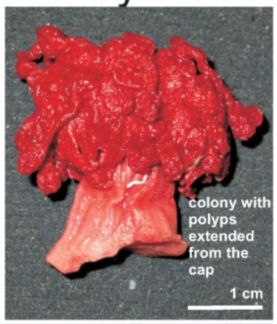


Paragorgia arborea **(NL ID code 8903)**

a.k.a. **bubble gum coral or rubber tree coral**
Found on the edge and slope between 400-1200 m, with large colonies documented off Cape Chidley, Labrador. Colonies are large irregular branching rubber-like trees, typically oriented in one plane, that can reach heights up to 2 m. The skeleton is not consolidated but is thick in diameter with a porous texture which gives the colony its flexibility. Colonies can be bright red, yellow or tan in colour. Branch tips are bulbous with polyps usually retracted within the calyx. The colony is supported by a thick base and large holdfast fused to hard substrates like cobbles, boulders, and rock outcrops. Often found with basket stars (a.k.a. tangle foot) attached to branches (see photo). Mature intact colonies > 1 m in height are rare. More likely to see small fragmented pieces of branch tips, which may be confused with *Anthomastus grandiflorus*, (sea mushroom) a small soft coral.

Alcyonacea: soft corals



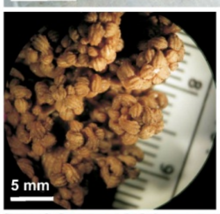


Anthomastus grandiflorus (NL ID code 8906)

a.k.a. **sea mushroom**

Found on the edge and slope between 200-1400 m. Individual colonies resemble small mushrooms and are usually < 5 cm in height but can reach up to 10 cm. Colonies are bright red and are characterised by a capitulum or cap. Polyps are large and are connected to the cap by long polyp tubes. The colony is supported by a stout basal stalk with a large base that is usually fused to hard substrates like pebble, cobble, boulders or other hard corals.

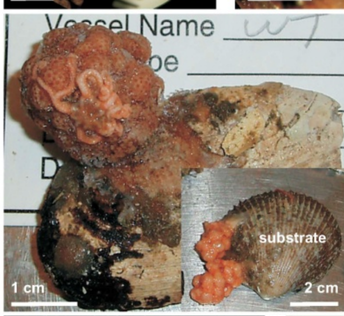
Note: Juveniles can occur in great numbers and may lack a developed stalk and base.

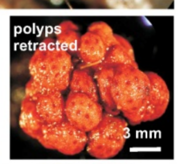


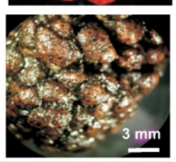
Capnella florida (NL ID code 8905)

a.k.a. **sea broccoli**

Found mostly along the edge and slope between 200-1300 m, with sporadic occurrences on top of banks. Colonies lack a true skeleton and maintain shape by hydrostatic pressure. Individual colonies are stout usually < 15 cm in height, with bare branches that terminate in clusters of non-retractable polyps. Individual polyps tend to be slightly curved towards the top with a faint ribbed pattern. Colonies are mostly black in colour with some brown, beige and salmon variations. Usually found attached to rock and gravel substrates with some living on live gastropods and sponges. Common to see juvenile basket stars intertwined within the branches.



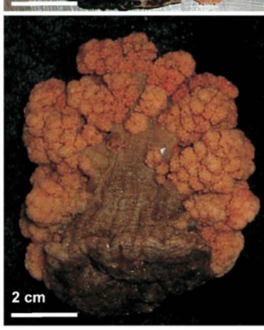




Gersemia rubiformis (NL ID code 8904)

a.k.a. **sea strawberry or sea cauliflower**

The only coral species found consistently on top of banks between 50-700 m. Colonies are small usually < 5 cm in height, and consist of tightly compacted club-shaped branches. Polyps are concentrated at the branch tips and are usually retracted within the calyx which creates a 'pin cushion' texture. Colonies can be vivid red, to pale pink, salmon, tan, and even dark brown in colour. Usually found on pebbles or shells but have been also observed attached to live gastropods. Common to see juvenile basket stars intertwined within the branches of a colony.



nephtheid species (NL ID code 8920)

a.k.a. **soft coral**

Nephtheids are a group of soft corals not yet identified to species level. Found at all depths. Individual colonies have a main stem void of polyps. Branches are densely-covered in ball-shaped polyp clusters. Usually light salmon-colour. Found on shell and pebble substrates.

Easily confused with *Gersemia rubiformis*.

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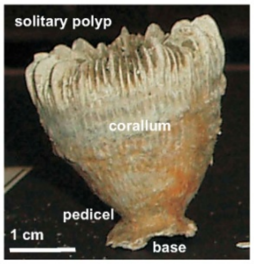
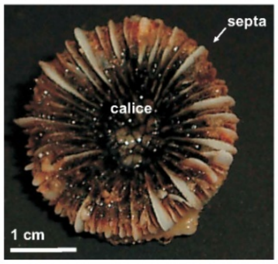
Scleractinia: solitary cup corals





Vaughanella margaritata (NL ID code 8917)

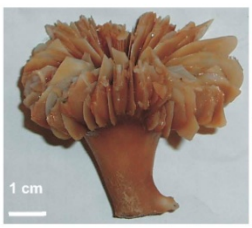
a.k.a. small cup coral

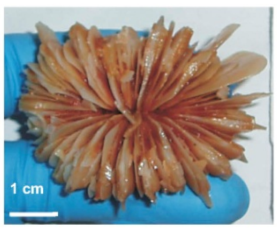
Found on the slope east of Hudson Strait and off Hopedale Saddle in deep waters > 1000 m. Historically found off western slope of Beothuk Knoll (46°04'40"N, 46°42'15"W), but no current records exist. Individual animals (polyp) are small (< 2.5 cm). The corallum, the hard part of the skeleton, is conical tapering to a narrow stem called the pedicel. The calice, the top surface of the corallum, is cylindrical. Small uniformed septa, radial partitions that divide the calice into sections, partially extend past the calice border. Individuals are usually attached by the base to hard substrates, like rock walls and outcrop.

Flabellum alabastrum (NL ID code 8914)

a.k.a. **fan-like cup coral**

The most common species of cup coral found in the region along the edge and slope between 200-1400 m off Southeast Baffin Shelf, Flemish Cap, southwest Grand Bank, Northeast Newfoundland Shelf and Labrador Shelf. Individuals are small-medium (< 8 cm in height) with a fan-shaped corallum that tapers to a pointy base. The calice is elongated and compressed in the centre. Septa are large, uneven, and do not exceed the calice border. Individuals are unattached and lay on top of soft substrates like muds.

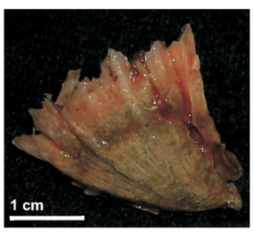


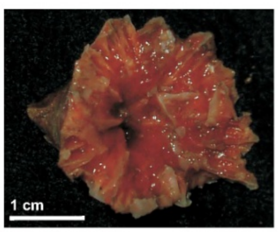


Desmophyllum dianthus (NL ID code 8916)

a.k.a. **large cup coral**

Found on the edge and slope off the southwest Grand Bank between 700-1000 m. Historically found off Makkovik Bank, and Southeast Baffin Shelf. Individuals are relatively large (< 10 cm). Corallum consists of a large calice supported by a long smooth pedicel that tapers sharply towards the base. Septa are large and uneven, and extend well beyond the calice border. Individuals are attached by the base to hard substrates like rock walls and outcrops.



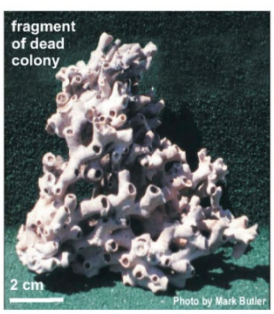


Dasmosmilia lymani (NL ID code 8918)

a.k.a. **horn-like cup coral**

Only one sample found off southwest slope of Grand Bank at 457 m. Individual was small (2 cm in height), fragile, and the corallum fractured (common for this species). Corallum was horn-shaped tapering towards the base. Calice was elliptic. Septa appear to be small, even, and did not exceed the calice border, but difficult to determine due to damaged specimen. Individuals are most likely unattached or can be attached to a fractured piece of corallum from the parent.

Scleractinia: colonial (reef-forming) corals



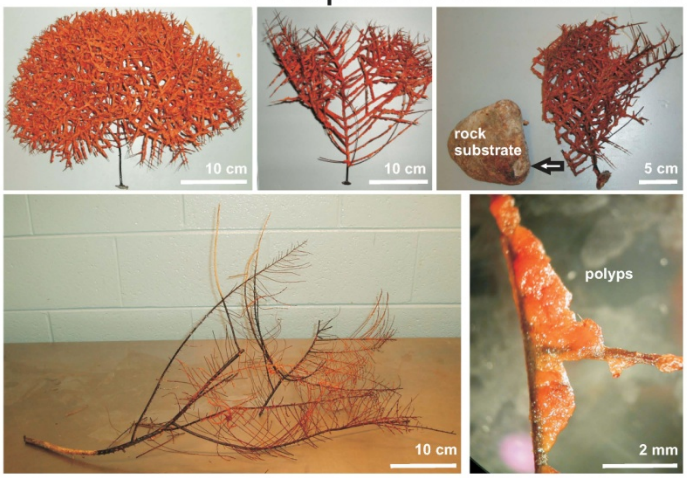
Lophelia pertusa (NL ID code 8911)

a.k.a. **spider hazard coral**

To date, known only from the Stone Fence, on the southeast corner of the Scotian Shelf, between 200-1000 m. No specimens have been documented in the Newfoundland, Labrador, or Baffin Island Regions.

It is the only reef-forming coral documented off Eastern Canada. Colonies can create large deep-sea reefs that are metres in height and kilometers in length as seen off Norway. Colonies are comprised of living and dead individuals that are easily damaged. Samples are more likely to be small fragments (< 30 cm). Polyps are long and can be white or orange-pink in colour, housed within hard calcified polyp tubes that are crossed and fused.

Antipatharia: black-wire corals



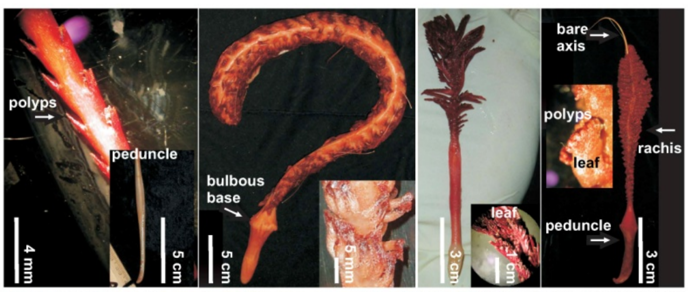
(NL ID code 8913)

Stauropathes arctica
***Bathypathes* species**

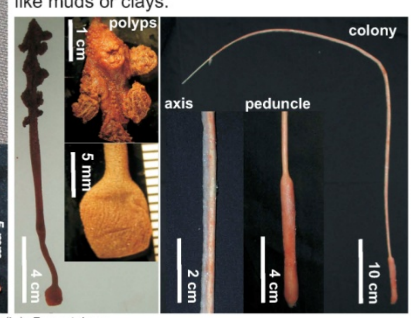
a.k.a. **black-wire coral**
Found on the slope between 700-1300 m. There are at least two species documented in the region but more may exist. Colonies are medium to large and can reach up to 80 cm in height. Skeleton is entirely black and consists of a main axis with stiff lateral branching. Branches are narrow with sharp pointy tips and can be crossed and fused together. In some species, the branches can face forward giving the entire colony a distinct front and back. Polyps are small, delicate, and bright orange in colour. They only occupy one side of a branch. Colonies are usually supported by a small oval basal plate that is fused to hard substrates like boulders and cobbles. Individual species are difficult to determine without a microscope.

Pennatulacea: sea pens

(NL ID code 8901)



a.k.a. **sea pens**
Found on the edge and slope throughout the Northwest Atlantic between 100-1500 m in depth. Sea pens are the most abundant and diverse coral group with 11 different species found in the region. Colonies consist of a main axis that is divided into two parts: the peduncle (the lower portion which is imbedded in sand or mud), and the rachis (the upper portion suspended in the water column). Individual polyps can be attached directly to the axis or can form polyp leaves, many polyps on a leaf-like appendage. The peduncle has a bulbous base that acts like an anchor to support the colony. It swells under hydrostatic pressure and is the key identifying feature for all sea pens. Sea pens are found in soft substrates like muds or clays.



Top row (L-R): *Distichoptilum gracile* (Verrill, 1882), *Anthoptilum grandiflorum* (Verrill, 1879), *Pennatula phosphorea* (L.), *Pennatula* sp.
Bottom row (L-R): *Halipteris finmarchia* (Sars, 1851), *Funiculina quadrangularis* (Pallas, 1766), *Umbellula lindahli*, *Pennatula grandis* (Ehrenberg, 1834), sea pen, sea pen.

APPENDIX B: Interview Materials

B.1 APPLICATION FOR ETHICS APPROVAL

"Mapping the distribution of deep-sea coral in the Northern Gulf of St. Lawrence using both scientific records and local ecological knowledge"

Researcher:

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Degree Program: Master of Science in Biology

Principle Investigators:

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Dr. Barbara Neis
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(709) 737-7244

Research Assistant: Laura Genge

Contact Person: If you have any questions or concerns about this study, please contact Emile Colpron (see researcher contact information above)

SUMMARY OF THE RESEARCH

The deep-sea corals of Atlantic Canada have recently received increased attention due to concerns raised about the impacts of bottom-fishing gear on deep-sea ecosystems, of which deep-corals are an integral part. While the distribution of deep-sea coral has been mapped for a number of regions in Atlantic Canada, Edinger et al. (2007) for example, no such records exist for the Northern Gulf of St. Lawrence.

The overall goal of this project is to combine the knowledge of local fish harvesters with the results of scientific research in order to map the distribution of deep-sea coral in the Northern Gulf of St. Lawrence. Four sources of information will be used; (1) fishery observer records, (2) groundfish survey records from the Department of Fisheries and Oceans (DFO), (3) interviews with local fish harvesters, and (4) direct participant observation onboard fishing vessels. This method is similar to that of Gass and Willison (2005) which used fishery observer data, DFO groundfish survey records and interviews with local fish harvesters to provide an overview of the distribution of deep-sea corals in Atlantic Canada (not including the Gulf of St. Lawrence).

The involvement of human participants in this project has two phases. In phase one, interviews with local fish harvesters will be conducted. This application is only concerned with phase one of the project and approval for phase two (participant observation onboard fishing vessels) will be sought at a later date. From these interviews with local fish harvesters we hope to obtain knowledge that would otherwise be unavailable. From their knowledge of local fishing grounds, we hope to identify areas where coral bycatch was observed. By interviewing older, experienced fishermen we also hope to learn about any changes in deep-sea coral abundance over time, which can be explained as changes in frequency and abundance of coral bycatch. Background information on their fishing careers will also allow us to identify changes in fishing gear, and if these changes had a direct effect in producing coral bycatch. Finally we hope to learn their opinions on the importance of deep-sea corals, whether conservation is important, and what conservation measures do they suggest?

This project is part of CURRA (Community-University Research for Recovery Alliance) which is a SSHRC funded initiative that includes researchers in both the natural and social sciences from Memorial University and beyond. The FFAW (Fish, Food and Allied Workers) is a community partner of CURRA and will be used identify the chairs of local fishery committees so that they may be contacted. Local fish harvesters from three communities will be interviewed in this study. In Newfoundland, study sites include the Port-Aux-Basques and Port-Aux-Choix areas, and the third study site will a fishing community on the Northern Gulf shore of Quebec yet to be determined. In each of the three communities we hope to interview 10-30 active and retired fish harvesters.

When contacting the chairs of local fishery committees, the project along with its goals will be explained. We will then ask they provide us with a list of names and phone numbers for local fish harvesters they consider to be the most knowledgeable about particular deep-water fisheries or fishing grounds. Selected harvesters will be contacted by phone to see if they would be willing to participate in a face-to-face interview. If necessary, participants may be asked to suggest other potential participants for the study (snowball sampling).

STATEMENT OF ETHICAL ISSUES

Consent and Participant Rights

Our method is aimed at ensuring that interview participants are fully aware of the goals and implications of this research, and are fully aware that their participation is completely voluntary. This will be formally established through the use of a consent form. The consent form summarizes the research project being undertaken as well as establishes the participant's rights in the interview. These rights include the right to withdraw from the interview at any time and to refuse to answer any specific question without explanation.

Confidentiality and Anonymity

The list of people interviewed for this project will be kept confidential. Each interview will be assigned a number and researchers will keep the master list of names and contact information in a locked filing cabinet on campus in St. John's, along with the interview transcripts and charts. No part of the interviews will be voice-recorded. Confidentiality is also an issue that arises once the project is completed. To address this issue we have included an archival deposit/ access form which allows interview participants to decide what is done with their nautical charts and interview transcripts once the project is complete.

Risks and Benefits

We think the risks of participating in an interview are minimal. The interview will last approximately one hour. There is the possibility that a local community member or someone who knows the participant might suspect they provided a specific piece of information. However, as deep-sea coral is not commercially valuable, we believe the risk posed to local fish harvesters is minimal. There is a limited risk in that the information gathered during these interviews could contribute to future decisions to close certain marine areas to some gear types, or potentially all bottom-fishing.

By participating, local fisher harvesters can benefit by contributing to the overall knowledge of deep-sea corals in the Northern Gulf of St. Lawrence. Their experience can provide us with information not scientifically available. Their contribution also has the opportunity to influence knowledge that may be used in future management decisions. One of the main objectives of CURRA is to encourage cooperation and partnerships between scientists and local resource users. As part of this commitment we plan to communicate the results of our research in follow-up meetings in each of the three communities included in this study. This allows interview participants to see how the information they provided has been used. Acknowledgement of the importance of the information they provided may act as a source of empowerment for interview participants.

Special Considerations

In some cases, participants may be unable to read and comprehend the Consent Form or the archival access/ deposit form. In such situations there is a third party witness form, a copy of which is attached to this application. When a third party is present they will be asked to witness the verbal explanations of the research, participant rights, and associated forms. Their signature of the third party witness form will signify their satisfaction with the explanations provided.

Where a third party witness is not present, the researcher will read slowly and carefully through the forms, taking time to discuss each statement, prior to asking the participant to sign it.

NB: French translations of the interview protocol, consent form, and archival deposit form will be submitted to ICEHR before field work on the Québec north shore begins.

References

Edinger, E., Baker, K., Devillers, R. and Wareham, V. (2007). Coldwater corals off Newfoundland and Labrador: distribution and fisheries impact. WWF-Canada, Toronto, Canada, 41 pp.

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

B.2 PARTICIPANT CONSENT FORMS

Title: Mapping the distribution of deep-sea corals in the Northern Gulf of St. Lawrence using both scientific and traditional knowledge

Researcher:

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Degree Program: Master of Science in Biology

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Dr. Barbara Neis
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Research Assistant: Laura Genge

Contact Person: If you have any questions or concerns about this study, please contact Emile Colpron (see researcher contact information)

PARTICIPANT CONSENT FORM FOR INTERVIEWS WITH LOCAL FISH HARVESTERS

I am a student at Memorial University. This research is part of my master's project. The goal of this project is to combine the knowledge of local fish harvesters with the results of scientific research in order to map the distribution of deep-sea coral in the Northern Gulf of St. Lawrence. The research is part of the CURRA (Community-University Research for Recovery Alliance) initiative. CURRA is funded by SSHRC (Social Sciences and Humanities Research Council) and includes researchers in both the natural and social sciences from Memorial University and beyond.

I am looking to interview local fish harvesters who fish in the Northern Gulf of St. Lawrence. From these interviews I am hoping to learn which fishing grounds have produced coral bycatch. I also hope to learn about trends in coral abundance over time. Finally I hope to hear the harvester's opinions on the importance and conservation of deep-sea coral. In addition to the interviews with local fish harvesters I will be using fishery observer records and DFO ground-fish survey records. I also hope to go to sea to observe the fishery first-hand and learn more about the gear-types used in the region, and their effect on coral bycatch.

During the interview we will ask you about your background and experience. We will then ask you to describe the changes in your fishing career in terms of (a) changes in the types of fish and shellfish you have harvested and (b) changes in the gear-type used. We will then proceed to ask you questions about your knowledge of deep-sea corals. You will be asked to write down where you have and have not encountered deep-sea corals on a nautical chart. We will also ask you whether you believe there has been a decrease in the abundance of deep-sea coral during the duration of your fishing career. Finally we will ask you your opinion on the importance and protection of deep-sea corals.

The list of people interviewed for this project will be kept confidential. Each interview will be assigned and number and the list of names and contact information will be kept in a secure cabinet, separate from the interview transcripts and charts. No part of the interview will be voice-recorded. The interview will last approximately one hour, which may be an inconvenience. You should be aware that a local community member or someone who knows you might suspect you provided a specific piece of information.

However, as deep-sea coral is not commercially valuable, we believe the risk posed to local fish harvesters is minimal. We think the risks to you of participating in the project are minimal. By participating, you can benefit by contributing to the overall knowledge of deep-sea corals in the Northern Gulf of St. Lawrence. Your experience can provide us with information not scientifically available. Your contribution has the opportunity to influence knowledge that may be used in future management decisions.

You are free to participate or not participate in any part of this interview. You may decline to answer any question put to you, and are under no obligation to explain your decision.
You are aware of the potential risks and benefits associated with your participation in this interview, and you have been given the opportunity to ask questions and voice your concerns over these risks and benefits.

PARTICIPANT CONSENT FORM FOR INTERVIEWS WITH LOCAL FISH HARVESTERS

I have read the explanation about this study. I hereby consent to participate in this study. However, I realize my participation is voluntary and I am free to withdraw from the study at any time.

_____________________ _______________________ ___________

Name of participant Signature of participant Date

_______________________ _______________________ ____________

Name of Principal Investigator Signature of Principal Investigator Date

The proposal for this research has been approved by the Interdisciplinary Committee on Ethics in Human Research at Memorial University. If you have ethical concerns about the research (such as the way you have treated or your rights as a participant), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at (709) 737-8368

PARTICIPANT CONSENT FORM FOR INTERVIEWS WITH LOCAL FISH HARVESTERS

Third Party Witness (where necessary and available)

I have witnessed the researcher named below explain the research project and the contents of this consent form to the participant and I am satisfied that the participant understands the consent form and is aware of his/her rights with respect to participation in this interview.

____________________ ____________________ ____________

Name of 3rd Party Witness Signature of 3rd Party Witness Date

On behalf of Memorial University:

____________________ ____________________ ____________

Name Signature Date

B.3 PROTOCOL FOR INTERVIEWS WITH FISH HARVESTERS

Geographic sampling to be used

- Talk to the chairs of local fisheries committees in Port aux Basques / Codroy Valley, Port aux Choix, and a community on the Quebec shore of the Northern Gulf of St. Lawrence to be determined.
- Ask local fisheries committees to identify local fish harvesters which fish target species and / or use gear types known to produce coral bycatch.
- Interview fishermen from the three areas listed above as identified from local fisheries committees. We hope to interview at least 10 fishermen in each community and will interview a maximum of 30.
- Ask for other potential interviewees during the interviews (snowball sampling).

First contact (telephone)

Hi. My name is Emile Colpron. I am a researcher at Memorial University working with the Community-University Research for Recovery Alliance, an initiative funded by the Social Sciences and Humanities Research Council. My project is looking at the distribution of deep-sea coral in the Northern Gulf of St. Lawrence. You have been identified as someone who has experience in the local fisheries and as someone who is knowledgeable about those fisheries. We would like to do an interview with you in which we will ask you about your fishing career, in particular reference to deep-sea coral. The interview will take approximately one hour to complete although the precise length depends on how much you have to say. Participation is voluntary and should you agree to participate, you will be free to refuse to answer particular questions and to withdraw from the study at any time.

B.4 INTERVIEW SCHEDULE

Ethics

- Go over the consent and archival deposit form reading/explaining what each paragraph means. Ask if they would like to read it through on their own or if they would like someone to go over the forms with them. If they indicate they would like someone from their household to go over the forms with them, and there is a third party present, have them read it. If there is no third party present but they don't want to go through it on their own, go over the forms to them, pausing to make sure each section is understood.
- Explain that participation in the interview is completely voluntary. If they agree to be interviewed, explain to them that they have the right to decline to answer any question without justification.
- Ask them to sign in appropriate places and check off appropriate selections for archival deposit. Their signature indicates that he/she understands what the research is about, that their participation is completely voluntary, and that they are consenting to being

interviewed. Interviewer also signs on behalf of Memorial University. Leave signed copies of consent and archival deposit forms with them.

Fishing experience and basic demographics

1. Age__________
2. Gender: M_____ F_____
3. Education level: <Grade 8_____Grades 9-11_____ Graduated High School____
4. Post-secondary training? ____
5. Formal training in fishing? Y_____ N_____
If yes, describe____
6. Length of fishing career:____________________
7. Have you always been based in this community? Y_____ N_____
8. Are you currently skipper______ or crew______ or retired______?

Fishing gear

1. Sectors in which you have fished? Inshore_____ Offshore_____
2. Target species and associated gear types used throughout career

Deep-sea coral bycatch

1. Have you heard of deep-sea coral?
2. Have you ever caught deep-sea coral as fishery bycatch?
3. In which fisheries (cod, halibut, turbot, shrimp, crab etc…) have you seen coral bycatch over your career?
4. Were different kinds of coral associated with different kinds of gear, or different fisheries?

NOTE: At this point produce the coral ID sheets, photos and actual specimens of coral as well as species commonly mistaken as coral (i.e. coralline algae)

5. Do any do these look familiar? Which ones? If so; (a) in which fisheries have you seen this species as coral bycatch and (b) do you remember what kind of gear you were using when you noticed this species coming up with the gear?

Chart work

Using the following color coding scheme, nautical charts will be used to show the distribution of deep-sea coral, as defined as areas of coral bycatch.

Map #1: Overview

Blue- All areas fishes
Green- All areas believed to contain deep-sea coral
Red- Areas where a decline in coral bycatch is believed to have occurred.

Map #2: Deep-sea coral
If the distribution of particular species is known it will be marked on a separate map of the same area. A different color will be used for each species, and color guide will be recorded by researcher during the interview.

Map #3: Fishing
Areas fished will be broken down by target species and gear type on a third map. Different colors will be used, and a color guide will be recorded by researcher during the interview. Where possible, changes over time in fishing area, target species and gear type will be neatly labeled.

Deep-sea coral conservation

1. In your opinion, what are the things that tend to influence whether you get coral bycatch in your fishery? The amount of bycatch you get?
2. Are some fisheries more likely to produce coral bycatch than others?
3. Are some gear types more likely to produce coral bycatch than others?
4. Do you believe there has been a decrease in coral bycatch over time? Since when?
5. In your opinion, are deep-sea corals important? Why or why not?
6. What do you believe should be done to conserve deep-sea corals?
7. In your opinion, what is the relationship between deep-sea corals and sustainable fisheries?

POST INTERVIEW

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- Make sure transcripts and charts are labelled with place, date, interviewer initials and interview number
- Keep a master list that has both the actual name of the participant and the associated interview number

B.5 ARCHIVAL DEPOSIT FORM

Once the research project is complete, it is up to you what is done with the nautical charts and interview transcript. However, as part of the research integrity policy at Memorial University, interview materials will be kept in a secure location by the researchers for 5 years after publication of the master's thesis.

The information you provide may also be a valuable resource for other, future researchers. If you are willing to have a copy of the interview transcripts made available to other students and researchers from Memorial University, please indicate below. If you agree to deposit the interview transcript for future use, please keep in mind that the list of names will remain confidential.

Therefore anyone using this resource would not be permitted to use your real name in any published document, public presentation, or any other publicly accessible media without your permission. You can also request that future researchers only have access to the interview transcripts with your written permission.

If you are uncomfortable with any of the above options, you may ask to have the interview transcripts and charts retained only by the research team, or even destroyed after the completion of the project.

Finally, you may wish to receive a copy of the interview transcripts for your own personal use.

Please check your preferred options below:

I hereby authorize:
OPTION 1:_____ Secure placement of the interview transcripts and charts with the Community-University Research for Recovery Alliance project at Memorial University.
A. Access up to the discretion of CURRA research team_____
B. Access only with written permission_____
OPTION 2:_____ Secure retention of interview transcripts and charts only by the research team
OPTION 3:_____ Destruction of the interview transcripts and charts after the completion of the project
OPTION 4: Do you wish to have a copy of the interview transcript sent to you?
YES_____ NO_____

Name____________________ Signature___________________ Date_______________

Signing of behalf of Memorial University:

Name____________________ Signature___________________ Date_______________

ARCHIVAL DEPOSIT/ ACCESS FORM

Third Party Witness (where necessary and available)

I have witnessed the researcher named below explain the contents of this Archival Deposit/ Access form to the participant and I am satisfied that the participant understands this form and the various options open to him/ her with respect to access to and use of interview transcripts and charts.

Name___________________ Signature___________________ Date_______________

Signing of behalf of Memorial University:

Name___________________ Signature___________________ Date_______________

The proposal for this research has been approved by the Interdisciplinary Committee on Ethics in Human Research at Memorial University. If you have ethical concerns about the research (such as the way you have treated or your rights as a participant), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at (709) 737-8368.