IDENTIFICATION, DISTRIBUTION, AND CONSERVATION OF DEEP-SEA CORALS IN CANADA'S NORTHWEST ATLANTIC

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IDENTIFICATION, DISTRIBUTION, AND CONSERVATION OF DEEP-SEA CORALS IN CANADA'S NORTHWEST ATLANTIC

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ABSTRACT

Deep-sea corals are long-lived, slow-growing benthic animals and are generally considered important for deep-sea biodiversity. Deep-sea corals in Newfoundland, Labrador, and eastem Canadian Arctic waters were mapped using incidentalby-catch from multispecies scientific surveys and fisheries observations. Todate(2004-2009), 44 deep-sea coral species have beendocumented, including 330ctocorals, eight scleractiniansandthreeantipatharians. Coraldistributionswerehighlyclustered, with most species co-occurring in fishing sets. Five coral species diver**sityandabundance** hotspots were delineated: Hudson Strait regioin, Labrador shelf edge and slope, Orphan Spur-Tobin'sPoint, Flemish Pass and sounlwestGrand Banksshelfedgeandslope Corals are under threat from bottom tending fishing. Impacts from mobile and fixed gears can include dislodgement, breakage, and complete removal. Although several protected areas have been established and other candidates have been identified, protective measures for deep-sea coral in Newfoundland and Labradorareinsufficient

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Dedicated to
my Aunt Elaine (1947-199S),
my role model and inspiration in life

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LIST OF ACRONYMS

Bedford Institute of Oceanography

Centre of Expertise for Aquatic Habitat Research

Canadian Broadcasting Corporation

Canadian Coast Guard Ship

Centre of Expertise

Committee On Status Of Endangered Wildlife In Canada

Department of Fisheries and Oceans Canada

Ecologically and Biologically Significant Areas

Environmental Non-governmentOrganization

Ecosystem Research Initiative

Fisheries and Aquaculture Management

Groundfish Enterprise Allocation Council

General Bathymetric Chart of the Oceans

International Council for the Exploration of the Sea

International Governance Program

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Integrated Taxonomic Information System

Local Ecological Knowledge

Large Ocean Management Area

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United Nations General Assembly

UNESCO-IOC Register of Marine Organisms

Vulnerable Marine Ecosystem

Vessel Monitoring System

Working Group on Ecosystem Approach to Fisheries Management

World Register of Marine Species

1 INTRODUCTION TO DEEP-SEA CORAL IN THE NEWFOUNDLAND AND LABRADOR REGION, NORTHWEST ATLANTIC OCEAN

Deep-seacorals (Phylum: Cnidaria), alsoknownascold-watercorals, are vibrantly-coloured animals that look like planlsand come in various shapes and sizes. First discovered by deep-sea expeditions in the late 17005 (Pontoppidan, 1755)theyare dredged from the sea floor from all over the world atalldepths(Freiwaldetal., 2004) The study of deep-sea corals is costly and time-consuming duetothe great depths of theenvironementtheyinhabitandtheassociatedlogisticsofconducting research in the

increasing due to the functional role(s) they play in providing habitat for other species and contributing towards habitatcomplexity(Robertsetal., 2009). Until recently, little was known about the distribution of deep-sea corals in the northwest Atlantic with the exception of sporadic occurrences from pioneering expeditions (Moseley,1881; Verrill, 1885; Agassiz, 1888; Jourdan, 1895; Pax, 1932; Kramp, 1942;Litvin & Rvachev, 1963; Nesis, 1963a; Nesis, 1963b)withfewexploringNewfoundlandandLabrador waters (Jourdan, 1895; Litvin&Rvachev, 1963; Nesis, 1963a; Nesis, 1963b). The purpose of this thesis is to help fill information gaps on corals from the northwest Atlantic by fulfilling three primary goals

- To identify deep-sea coral species and frequencies of occurrence;
- TomapthedistributionsofcoralsoffthecoastsofNewfoundland, Labrador, and

iii. **Todiscusspotentialconservationstrategiesandrecommendalternativeactions** for national and regional resource managers

Chapter 1 introduces the thesis and includes; what are deep-sea corals, where they are found, why theyareimpcrtant, andthreatstotheirexistence. Inaddition, background information on historical occurrences will be described. Subsequent chapters focus on basic biology of deep-sea corals, threats to deep-sea corals, andpreviouscoral

Chapter 2 addresses two goals:

i. To identify deep-sea corals; and

This chapter was presented at the 3'd International Deep-Sea CoralsSymposiumin Miami, Florida in 2005 and is published in a special edition of the Bulletin of Marine Science (Wareham & Edinger, 2007)

Chapter 3 provides an update on the ongoing processof identifyingandmappingdeep-sea corals in the northwest Atlantic, building on the existing datasetdeveloped by Wareham and Edinger (2007). Collectively, it will be used to identifyandhighlightareas for protection within theNewfoundland, Labrador, and eastern Canadian Arctic regions Chapter3was published as Wareham (2009a) as part of Department of Fisheries and Oceans Canada (DFO) Technical Report summarizing researchconducted in the Newfoundland and Labrador Region titled *"The Ecology of Deep-sea Corals of Newfoundland and Labrador Waters: Biogeography, Life History, Biogeochemistry, and RoleofCrilicalHabitaf* (Gilkinson & Edinger, 2009)

Finally, Chapter 4 highlights progress on coral conservation todate, discusses management strategies to identify priority areas for future protection, and outlines challenges the Newfoundland and Labrador Region faces. This chapter concludes with recommendations for addressing these challenges in ordertosucc**essfullyprotectcorals**

Four Appendices follow the thesis. Appendix 1 provides a *Syslematic Lisl* of *Phylum*

Baffin Island,Canadaemphasised in bold. Appendix 2 isa "user-*friendly" Identificalion GuidetoDeep-SeaCoralsNewfoundland,Labrador, andBaffinIsland, Canada, in* poster format (Wareham, 200gb). I developed the poster, and itwas reproduced by

theposterisincludedona compact disk in Appendix 3. The compact disk also includes Adobe PDFs of maps and data used in mapping of deep-sea corals published in Chapter 2 (Wareham & Edinger, 2007) and Chapter3(Wareham,2009a).Appe*ndix4, Collection Prolocols for Corals and Sponges for Newfoundland, Labrador, andBaffinIsland, Canada,* contains two examples of standard deep-sea coral collectionprotocolscreated for this thesis and utilized by DFOstaff,and regional fisheries observers (SeaWatch

There are several limitations regarding data interpretation pertaining to Chapters 2 and 3. Data used in this thesis were collected byDFOand by the Fisheries Observer Program (FOP). Both sources sample from a variety of substrates usingdifferentgear **types. For example, DFO research vessels sample with a Campelen Trawl used on** relatively level sea floors and are limited to depths < 1,500m. EachDFOsurveysetis standardizedbydepthandtowduration(seeMcCallum&Walsh, 1996). The need for consistent tow speed and distance leadstoa bias that favours level sea floor environments, excluding steeper slopes and canyons. On the other hand, data from the Fisheries Observer Program are derived from commercial vessels using a variety of gear types,representingpreferredfishingareasbasedonpastcatchrates and past experience of individual skippers. Observer data incorporates many fisheries from a variety of depths, gear classes (i.e. mobile and fixed), geartypes(e.g.shrimptrawl, twin trawl),marinehabitats(e.g. steepcanyons), andseafloorsubstrates(e.g. boulders fields,mud, orsand).Inshort, DFOresearchdataarebiasedtowards 'trawlable' substrates and observer data are biased towards preferred fishinggrounds

The geographic scope of this thesis incorporates a large portion ofthenorthwestAtlantic offthecoastsofNewfoundland, Labrador, andsoutheastBaffinIsland(Fig. 1.1).It encompasses the Northwest Atlantic Fisheries Organization (NAFO) fisheries regulatory areadivisions; 3KLMNOP(Newfoundland), 2GHJK(Labrador), andOAB(easternBaffin Island). Data for this thesis was gathered from DFO research surveys(2003-2008), as well as from a partnership with industry (Northern Shrimp Survey). A third important data SQurce was from fisheries observers on board commercial fishing vessels operating within the NAFO regulatory areas within Canadian jurisdiction

All coral taxa recorded during the study were incorporated into the database. Based on the Integrated Taxonomic Information System (ITIS), taxa were documented from three subclasses: Octocorallia (;Alcyonaria), Hexacorallia(;Zoantharia),and Cerianthipatharia(seeAppendix1). Octocoralsinciudedtwoorders; pennatulaceans (sea pens) and alcyonaceans (soft corals and gorgonians). Hexacorals included scleractinians(stonycupcorals);andCerianthipathariainciudedantipatharians(black-wire corals). There were no hydracoralsrecorded

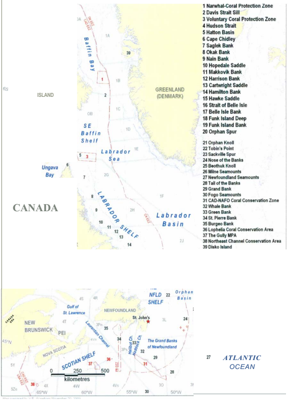


Figure 1.1. Map of study area highlighting bathymetric features off eastern Canada

There are various other papers on deep-sea corals to which I have contributed, butare not included in this thesis. We have described methods forworkin9 with fisheries observers(Warehametal., 2007), andcoraldistributionsintheNAFO region (Fulleret al.,2008). Wehaveanalysisedthedensitiesofcoralsandspongeswith associated fishing efforts in proximity to Hanon BasininNAFOdivisions2G-OB (Kenchingtonetal., 2010; Wareham et al., 2010). We have documented the ecological importance of corals in Newfoundland and Labrador waters to fisheries species (Edinger etal., 2007b), and fisheriesimpactsuponcorals(Edingeretal.,2007a). WehavedescribedAdenosine triphosphate and lipid biochemistry of several species of corals (Hamoutene et al., 2008a, b),and tissue stable isotope geochemistry of 11 species of deep-sea corals from AtianticCanadianwaters(Sherwoodetal., 2008)

Corals are simple animals, referred to individually as polyps(Birkeland, Ig96; Ruppertet al.,2004; Hopley, inpress).Eachpolypiscomposedofaring(s)0ftentaclesusedfor capturingfood,a mouth for eating, and a tube (actinopharynx orstomadem)leadingtoa central gastrovascular cavity (coelenteron) for digesting food. Corals can be solitary,

known tropical reef·building varieties are found in shallower warmer equatorial waters

They are restricted to the photic zone because they have endo-symbiotic relationships with algae and are referred to as zooxanthellate corals. The coral colony (:corallum) provides the substrate for algae to live in while theyphotosynthesize energy from the sun and convert it to food. In exchange, the algae excrete metabolic waste which is recycled as food by coral polyps (Muscatine & Porter, 1977; Hallock & Muller-Karger, In contrast, deep-sea corals are not as well-known becausetheyare rarely seen (Robertsetal., 2009).Mostspeciesarefoundbelowthephoticzone. Deep-sea corals arereferredtoasazooxanthellatecorals, whicharestrictlysuspensionfeeders. They depend entirely on currents and otheroceano9raphic processesto transport food to them, like zooplankton and detritus, which has been imported from the water column nearthewatersurface(Freiwald, 2002; Sherwoodetal., 2008).Currentsnotonlycarry food but also prevent accumulation of silt, which can smotherthepolyp(Robertsetal., 2009)

Basedonanatomydeep-seacoralscanbedividedintoseveralmaingroups: octocorals, scleractinians, and antipatharians. Stylasteridae and Zoanthidaeare two additional 9roups(Cairns, 1992; Ocaña & Brito, 2004) but were not found within the study area, therefore are not covered. Octocorals(ClassAnthozoa: Subclass Octocorallia) include the90r90nians, soft corals, and pennatulids(sea pens). Thisgroupiseasily distinguishable. Each polyp consists of eight tentacles all containingsc/erites-special internal structures constructed of calcitic calcium carbonate (Robertsetal., 2009) Almost all species in this group are colonial with the exception of onegorgonian(Bayer & Muzik, 1976). Gorgonians have a hard or consolidated internal skeleton which is constructed of either proteinaceous gorgonin, calcium carbonate (calcite or aragonite) or a mixture of the two (Bayer, 1973). Softcoralshaveahydroskeletonand rely on water andhydrostaticpressuretomaintaintheirshape(Fabricius&Alderslade, 2001) Similarly, sea pens maintain their shape using hydrostatic pressure but benefit from a central internal calcareous axial rachis, for added support and m**ovement(Williams,**

Scleractinians (Class Anthozoa: SubclassHexacorallia), also known as the stony corals, **can be found as colonial "reef-builders" or solitary cup corals. Most deep·sea species** are the latter with few exceptions (Cairns, 2007). Stonycoralsare easily identified by theireXDskeletons constructed of aragonitic calcium carbonate

ThefinalgrouparetheAntipatharians(ClassAnthozoa:SubclassCeriantipatharia), also known as the black-wire corals. Members of this group are all colonial.Polypsare simple, containing six tentacles and lacking sclerites. They have a unique internal chitinous skeleton for strength and support, while maintaining flexibility. The skeleton is **cDveredwithtinyspines.Taxonomicidentificationofthisgro**up is difficult. Species identification requires close inspection of polyps (size and structure),spinesand skeletonmorphology(Goldsbergetal., 1994; Opresko, 2002; Molodtsova & Budaeva, 2007)

Corals may be the longest living animals on Earth with some specie5 reaching several thousandyearsinage(Roarketal., 2006; Robertsetal., 2009). Growthratesformany **deep-seacoralsareunknown, howeversomespecieshavebeeninvestigated(Table** *1.1);PrimnoaresedaeformisGunnerus,* 1763(Risketal., 2002; Sherwoodetal., 2006), KeratoisisornataVerrill, 1878(Roarketal., 2005; Sherwood&Edinger, 2009), *Desmophytlum dianthus* Ehrenberg, 1834 (Risk et al., 2002), *Hatipteris willemoesi* (Kblliker, *1870; Wilsonetal., 2002), Chrysogorgiaagassizii(*Verrill, 1883; Vinogradov, *2000)andStauropathesarcticaLOtken,* 1871 (Sherwood & Edinger, 2009). All have extremely slow growth rates and some species can surpass 100'**50fyearsinage** (Sherwoodetal., 2006;Sherwood&Edinger,2009)

Table 1.1. Summary of growth rates and associated studies for some deep-sea coral species. RG=RadialGrowth; AC=Axial Growth; EA=Estimated Age; TL=Total Length

Coral Species	Growth Rates & Estimated Longevity	References
Primnoaresedaeformis (gorgonian)	'RG = 83 ±6t0215 ±37 µm yr' 'AG=1.00±0.09t02.61±0.09cmyr' 'EA=18tol00yr (2009) 'EA=<700yr(2006!	Sherwood &Edinger, 2009; Sherwoodetal., 2006
Acanellaarbuscula (gorgonian)	'RG - >20 µm yr' 'AG=>0.30cmyr' 'EA = 30yr (growth nng counts!	Sherwood &Edinger, 2009
Keraloisis, *Isidella*, or *Acanellasp.* (gorgonians)	RGR- 50·160 µm yr' (Alaska, USA)	
Keratoisisomata (gorgonian)	'RG - 53 ± 9to 75 ± 11 µm yr' 'AG=0.93±0.08cmyr' 'EA=94±7t0200 ± 30yr	Sherwood &Edinger, 2009
	RG - 50-1 10 µm yr^{-1} (Davidson Seamount, off California, USA!	
	RG -111 µm yr^{-1} (Tasmania)	Thresheretal., 2007
	RG = 130· 290 µm yr' (New Zealand)	Traceyet al., 2007
Paragorgiaarborea (gorgonian)	AG - 0.8-4cmyr' (New Zealand &Norway)	Tracey et al., 2003; Mortensen & Buhl-Mortensen, 2005
Paramuriceaspp *(gorgonian)*	'1.62 ± 0.22 cm yr' 'RG - 92 ± 18 µm yr' to 205 ± 20 µm yr' 'AG = 0.56 ±0.05 µm yr' to 0.58±0.08cmvr'	Sherwood &Edinger, 2009 Sherwood &Edinger, 2009
Chrysogorgiaagassizii !gorgonian)	AG-lcmyr' (rate based on optimal growth)	Vinogradov, 2000
Halipteriswillemoesi (sea pen)	Small colonies: TL= 25 - 29 cm; AG=3.9±0.2cmyr'; EA= 7.1 0.7 yr **Medium colonies**: TL = 97 ±130 cm; AG=6.1 ± 0.3cmyr'; EA = 19.3 ± 0.5 yrs Large colonies: TL = 152 - 167 cm; AG=3.6±0.I cmyr'; EA= 44.3±2.0 yr	
Siauropalhesarclica (antipathanan)	'RG - 33 ± 11t066± 11 µm yr^{-1} 'AG=I.22± 1.46to I.36±0.20cmyr' 'EA=55±8t082±31yr	Sherwood & Edinger, 2009
Leiopalhesglaberrima (antipatharian)	RG-0.0145 mmyr' EA= 200yr (Flonda, USA)	
	RG ≤ 10 µm yr'	

Investigations into the histology of soft corals indicated that they too may exhibit slow growth rates especially in early stages of recruitment (Cordes et al.,2001 ; Sunetal., 2010). For example, newly settled *Drifa* sp. reached only 5 mm linear length in 7 months, while Duva *florida* exhibited no branching of polyps in 11 months, and *Gersemia fruticosareachedonly* 10 mm linear length in 7 months (Sun et al., 2010)

1.1.5 Reproduction

Most knowledge of coral reproduction is from tropical species with very little known aboutdeep-seaspecies. Sexualreproductioncanbeeitherhermaphroditicwithmale (spermatocysts) and female (oocytes) gametes located on the same colony, or gonochoristic with male and female gametes located on different colonies. Gonochoristic **species, alsoknownasunisexual, produceplanulalarvaewhichca**n develop from internal or external fertilization. Internal fertilization resultsineggsbeingfertilizedand developed within the maternal colony, known as brooding (Richmond&Hunter, 1990) External fertilization results in eggs being fertilized and developed within the water column, known as broadcast spawning (Richmond & Hunter, 1990)

Hermaphroditic species produce planula larvaeaswell, butspermatocysts and oocytes candevelopondifferentlocationswithinthesamecolony(i.e. mesentery, polYP, or colony), ormaydevelopatdifferenttimeperiodswithinthesamecolony (Rinkevich& Loya, 1979). This development of gametes can occur simultaneously orsequentiallywith oocytesdevelopingfirstfollowedbythedevelopmentofspermatocysts (Rinkevich& Loya, 1979). Oncefullydeveloped, planulalarvaearereleased intothe water column from the parent as mature planulae (Richmond & Hunter, 1990; Fabricius& Alderslade, 2001)

In Newfoundland waters reproductive biology of four species of soft corals (neptheids) hasbeeninvestigated(Sunetal., 2010). *Drifa*sp.wasfoundtobea hermaphroditic internal brooder. *Drifa glomerta* was found to bean internal brooderbutitis undetermined whether it is gonochoristicor hermaphraditic. Method of reproduction of twootherspecies,*D.f1orida*and *G. frulicosa*, wasnotdetermined(Sunetal., 2010)

Manygapsinourunderstandingofthegeneralbiologyofdeep-sea corals remain. There islittleinformationavailableonageofmaturity, fecundity, reproductionand recruitment, resilience and resistance to damage, and rates of recovery (Robertsetal., 2009)

1.1.6 Where Do Deep-Sea Corals Live?

Deep-sea corals are usually found in areas with pronounced bathymetric relief such as deep-sea canyons, seamounts, and along the continental edge, slope and rise (Deichmann, 1936; Nesis, 1963b;Tendal, 1992; Breezeetal., 1997; Macisaacetal., 2001; Mortensen & Buhl-Mortensen, 2004; Gass & Willison, 2005; Bryan & Metaxas, 2006; Wareham & Edinger, 2007; Wareham, 2009a). In Newfoundland and Labrador, deep-sea corals can be found on the continental shelfandedge<2OOm, andonthe continental slope between 200-2,000 m deep (Nesis, 1963ab;Gass&Wiliison, 2005; Mortensen et al., 2005; Wareham & Edinger, 2007; Wareham, 2009a), with some speciesdocumentedonthecontinental riseatdepthsof2,200m(Bakeretal., 2008;

Substrate preferences are species-specific based on availability of hard substrates as well as the physiology of individual species. Substrates can vary from abiotic (e.g boulders, cobbles, pebbles, and mud), tobiotic(e.g. other corals, bryzoans, sponges, andlivinggastropods), toevenanthropogenicsuchasabandonedfishinggear, and plastics (Wareham & Edinger, 2007; Bakeretal.,2008)

[redacted]

ROPOS DiveR1072).Othercoralssuchassolitaryscleractiniancup corals (e.g Flabellumspp.)simply reciineontheseafloor(Fig. 1.3)withnoattachment or anchored appendage (Mortensen etal.. 2006; Wareham & Edinger, 2007; Baker etal.. 2008)

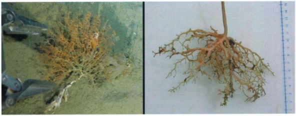


Figure 1.2. Photo of several gorgonian corals with calcified holdfasts: (left) *Acanella arbuscula*, and (right) *Radicipesgracifis*. Photos courtesy of DFO Canada

Figure 1.3. Photo of several solitaryscleractinian cup corals: (left) *Flabellum macandrewii* (Gray, 1849) taken at 361 min Desbarres Canyon, and (right) *Flabellum alabastrum(Mosley* 1876)takenat946m in Halibut Channel. Photoscourtesyof DFO

Most corals in Newfoundland and Labrador waters were found at depthsgreaterthan 200m(seeChapter2, Table2.1). Ithasbeenpostulatedthatthispossible restriction to deeper water may be due to several environmental factors such as strong currents along the edge of the continental slope, suitable substrates, and constant temperature ranges

Mostcoralsdependentonoceancurrentsandotheroceanographic processes (e.g upwelling, and gyres) to deliver particulate organic mattersuspended in the water column (Moore & Bullis, 1960; Tendal, 1992; Bryan & Metaxas, 2007), and winnow away fine sediments (Wainwright & Dillon, 1969). Most species need suitable hard substrates for attachment (Mortensen & Buhl-Mortensen, 2005). On the Scotian Shelf, deep-sea corals prefer temperatures that range between 3.5-13°C with high temperatures most likely limiting distribution (Mortensen etal., 2006), although ithas been found that some speciesofsoftcoralscantoleratetemperaturesaslowas-1 °C(Cimbergetal., 1981; Freiwald, 2002). However, the general distribution (i.e. onbanksvs. edge and slope) of deep-sea corals in the New10undland and Labrador region may be limitedlargelybycold water temperatures. The cold intermediate layerisa function 0ftheLabradorCurrent and brings sub-zero waters to the New10undlandand LabradorShelvesdownto-200 m(Dunbar, 1965; Petrieetal., 1992). Asa result, this may restrict distributions to deeper **waters on the continental slope where temperatures are more stable and often warmer,** compared to bank tops where temperatures can fluctuate (Nesis1963b). Some **gorgoniansintheNewfoundlandandLabradorregion,likePrimno*aresedaeformishave*** been found as shallow as 162monSaglekBankoffnorthernLabrador(Wareham& Edinger, 2007). This area in particular is known for strong currentswhich drain from Arctic waters via the Hudson Strait and Davis Strait (Piper, 2005). Such large influxes of cold water not only provide suitable substrates butdeliverfoodandoxygenaswell.More importantly, they maintain a constant temperature of cold water at much shallower depths than other areas within the region

Bryan and Metaxas (2006) observed that *Primnoa resedaeformis* and *Paragorgia*

where optimal water temperatures ranged 5.1 - 9.0 °e, along with other environmental

factors. Other studies from the Scotian Shelf suggest that high temperaturesarea limiting factor for deep-sea coral distributions (Mortensen et al., 2006). However, both studies may not fit the Newfoundland and Labrador region where l0wtemperaturesare more likely to bea limiting factor for coral distributions, particularlyon bank tops «200 m; Edingeretal., 2007b)

There is anon-going debate over the relative importanceofsubstrate versus oceanographicinfluences(e.g.currentstrength, temperature)ingoverningthe distributions of deep-sea corals (Nesis, 1963b; Bryan & Metaxas, 2006; Mortensenetal., 2006). Cinberg etal. (1981) used annual mean temperature and substrate as predictors of coral distributions. Nesis (1963b) linked a change in seatemperature with changes in species assemblages, while Mortensen et al. (2006) found that substrate and temperature are the most important variables influencing corals distributions. To what degree specific environmental faclors such as temperature, slope, substrate, salinity, and chlorophyli a influence the presence or absence of corals is not truly understood Bryan and Metaxas(2007) used known coral locations and severalenvironmental parameters to develop a predictive model for coral distributianS. How8ver, the inappropriate bathymetric scale used in their model precluded definitiveconclusions (Etnoyer & Morgan, 2007). As more environmental information becomes available and betterpredictivemodelsaredeveloped, keyfactorsinfluencingthe distribution of corals can be incorporated into predictive models and tested in terms 0ftheirrelative

1.1.7 EcologicalImportance

Deep-sea corals not only live in benthic ecosystems, they are importantfunctional components of these ecosystems. Their presence providestructure, adds structural and biological complexity to the deep-sea, and create micro-habitats for other species (Austeretal., 2005; Buhl-Mortensen&Mortensen, 2005; Auster, 2007; Etnoyer& Warrenchuk, 2007; Mooreetal., 2008; Bakeretal.,2008). SpecieslikeParagorgia *arboreaare* considered to be one of the most important habitat-formingdeep-seacoral species because of its' large size, reaching upt03m in height off eastern Canada (Mortensen & Buhl-Mortensen, 2005) and up to 10 m off New Zealand (Smith, 2001) Dense concentratioins of corals have been referred 10 as 'coral-gardens' off the Aleutian Islands(Cimbergetal., 1981; Krieger&Wing, 2002; Stone, 2006), 'gor90nianforests' on the Scotian Shelf (Lees, 2002; Mortensen & Buhl-Mortensen, 2005), and 'sea pen fields' off Newfoundland and Labrador (Wareham, 2009a). 'Gardens', 'forests', and 'fields' refer to large concentrations of corals with high species diversity 0r biomass abundance (Breezeetal.,1997; Watiing&Norse, 1998; Kreiger, 2001; Lees, 2002; Freiwaldetal., 2004; Mortensen & Buhl-Mortensen, 2005). High by-catch rates and fisheries observer photos indicate 'gorgonianforests' may exist off Cape Chidley, Labrador in close proximity to Hatton Basin (Macisaac et al., 2001; Gass & Willison, 2005; Wareham & Edinger, 2007; Wareham, 2009a;Warehametal., 2010; Fig. 1.4)

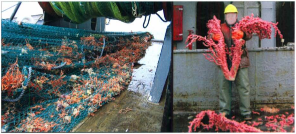


Figure 1.4. Photos of coral by-catch from the Hatton Basin area: (left) *Primnoa resedaeformis* entangled in a trawl net in 2007, (right) *Paragorgia arborea* from the Northern Shrimp Survey in 2006. Photos courtesy of DFO Canada.

Fish utilization of such 'forests' as well as other coral habitats is analogous to the interaction between trees and birds. The physical structure (=corallum) of a large gorgonian coral can dissipate energy from localized near-bottom currents (Zedel & Fowler, 2009), providing rest areas for smaller marine life (Auster et al., 2005; Costello et al., 2005). Corals also create forage areas, act as barriers between predator and pre and provide safe havens for juveniles and egg masses (Etnoyer & Warrenchuk, 2007b; Moore et al., 2008; Roberts et al., 2009). *In situ* examples of coral-structured habitats from the southwest Grand Banks are illustrated in Figure 1.5.

When groundfish diversity and abundance were compared with deep-sea coral distributions off Newfoundland and Labrador, weak but statistically significant correlations indicate goundfish utilize some corals, but relationships may not be obligat (Edinger et al., 2007b). Results may be scewed by the large scale of the study area combined with relatively small dataset (2 years). Other studies have shown stronger results due to direct observations using gillnets (Huseb0 etal., 2002) and video observations(Austeretal., 2005; Costelloetal., 2005; Mortensenetal., 2005)

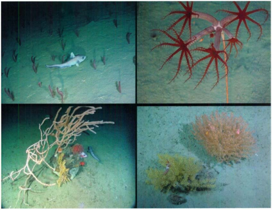


Figure 1.5. Photos of *in situ* coral habitats documented on the Southwest GrandBanks (top left) grenadier swimming within a *Pennatulasea* penfield in Desbarres Canyon at 900 m; (top right) close-up of *Umbeliulaencrinus(Linnaeus*, 1758) colony in Desbarres Canyon at 1657m. Note the small mysids hovering between the polyp5; (bottom right) *Acanthogorgia armata* colony with a shrimp resting within *anAcanellaarbusGulacolony;* (bottomleft)redfishandspottedwolfish, listedasthreatened(COSEWIC, 2001) resting around a small bouldercQvered with corals, including: *Keratoisisornata,Anthomastus* spp., Acanthogorgiaarmata(Verrill, 1878), neptheids, andsponges. Noteinitial

curled around the base of the *K. ornata* colony. Photos courtesy of DFa Canada

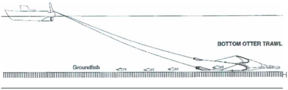
1.2.1 **BottomFishingPractices**

Therearemanyanthropogenicthreatstocoralsbutthemostprevalentarebottom fishing practices and fishing gear that come in eontaetwiththe sea floor (Probert, 1997; Watling & Norse. 1998; Fossa etal., 2001 ; Hall-Spenseretal., 2002; Grehanetal.,

following seetion will describe bottom fishing gear types used intheNewfoundlandand Labrador region and discuss how each impacts deep-sea corals. 0therthreatsare diseussedaswell, buttoalesserdegree

Bottom fishing gear can be divided into mobile and fixed-gear classe**S.Mobilefisheries** aetively pursue the target species and ean involvetrawling, dredging, or seining (Figs 1.6& 1.7). Fixed gearfisheriesusea sit-and-waitstrategy, where the gear is positioned in one location with the purpose of entanglement, entrapment, or hooking the target speeies. Deep water fixed gear fisheries in Newfoundland and Labradoruseerabpots, longlines, andgillnets (Figs. 1.9-1.11)

Trawling, also referred toasdragging, is the most widely-used fishingmethodinthe northwestAttantie (Fulieretal., 2008). Thereareseveraltypesoftrawls used in the Newfoundland and Labrador region; otter (Fig. 1.6), twin(Fig. 1.7), triple, and shrimp Trawling involves the dragging ofa large net aeross the sea floor. The mouth of the net is held open by the forward motion of the vessel combined with the spreadingaetionof the trawl doors as well as floats positioned along the headline (Fig. 1.7). While the basic principle of trawling has not changed sinee it's ineeption in the 14[th] eentury(March, 1953), technolo9icaladvanceshaveimprovedcatchefficiencyandadaptabilityoftrawls to operate in a variety of habitats



Fi9ure 1.6. Illustration of an otlertrawl used in the Newfoundland and Labradorre9ion (DFO, 1997)

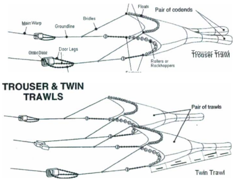


Figure1 .7. Illustrationsoftrousertrawl, twintrawl, andcomponents used in the Newfoundland and Labradorregion (DFO, 1997)

[redacted]

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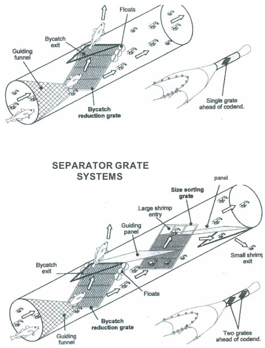

Figure 1.8. Illustrations of separator grates and components (DFO, 1997)

Trawling has been compared to ploughing a field or clear-cutting a forest (Watling & Norse, 1998; Anderson & Clark, 2003). Once trawled impacted areas becomes more homogeneous through mortalities and removal of biotic components such as large benthic megafauna (e.g. corals, hydroids, sponges). Trawling also alters abiotic components such as boulders, sand and mud-dominatedenvironments (Auster & Langton, 1999; Hall-Spenser, 2002; Mortensenetal., 2005; Edingeretal.,2007a). Trawl doors can weigh in excess of one ton each and create deep furrows in soft substrates as they are dragged during normal use (Roberts, 2002; Watling, 2005). It has been shown that trawl doors can impact and destroy certain infaunal taxa (Gilkinsonetal., 1998) Experimental studies carried out in eastern Canada have shown that the combined effects of trawling can cause damage and mortality to epifauna and infauna (Prena etal., 1999: Kenchingtonetal., 2001 ; Gordon etal., 2003) and change sedimentstructural properties (Schwinghameretal., 1998)

Commercial trawling is carried outona large spatial scale with preferred fishing areas repeatedly fished as seen on the Grand Banks of Newfoundland (Kulka & Pitcher, 2002; DFO, 2006). Individualtowscanbeconductedover1-10hrs. Theoverallfootprintcan be vast, particularly on an accumulative basis. However, thedeg**reeofimpactwillvary** depending on the biota present in the area being trawled. For example, in structurally complex coral habitats, the initial pass is the mostdamaging(Kriger&Wing,2002; Anderson & Clarke, 2003; Rice, 2006) resulting in largequantitiesofcoralby-catch (Probertetal.,1997; Kreiger, 2001)

Other mobile gear types such as dredges can have similar effects on the sea floor as **trawling. Dredges target soft sediment habitats and can damage infaunal communities** (Gilkinson et al., 2003) as well as megafauna communities *(Veale* et al., 2000; Thrush & Dayton, 2002)

Fixed gear fisheries (e.g. crab pots, gillnets, longlines) have also been shown to capture and damage deep-sea ccrals(Huseb0etal., 2002; Mortensenetal., 2005; Wareham &

Edinger, 2007). Although fixed gears are stationary, spatial coverage can still be significant because these gears are often linked. In the Newfoundland and Labrador region, crab pots are linked together as a string of baited traps, called 'strings' or 'f1eets', with upt050 pots per fleet (Fig.1.9). Impacts occur when the fleetisretrieved, causing the crab pots to be dragged across the sea floor where they can ensnarl and entangle

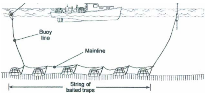

Figure 1.9. Illustrationofcrabpotgearconfigurationusedinthe Newfoundland and Labrador region (DFO, 1997)

Bottom gillnets operate under the same principle, andean becomprised of many panels (91.6 m per panel) strung together with up to 70 panels perfishingset(Benjaminsetal., 2008). How the net is positioned in the water column depends on thetargetedspecies Forsemi-pelagicfishes, theglllnethangs in the water column like a giant wall near the sea floor (Fig. 1.10). The top of each gillnet panel is outfitted with floats (float line) and the bottom with lead-rope (lead line). In Newfoundland and Labradorgroundfish fisheries, some fishers set bottom gillnets with no floats, which allows the panels to bunch together vertically for purposes of entangling the target species(W. DeGruchy, SeaWatchLtd., personal communication, Sept. 5, 2007)-thismethodisnotillustratedin Figure 1.10. Regardless of how the net is positioned, gillnetshavebeenshownto capture and damage corals (Mortensen et al., 2005; Gass & Willison, 2005; Wareham & Edinger, 2007)

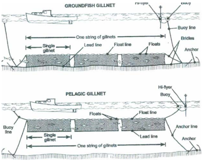

Figure 1.10. Illustrations of gilinet configurations and components (DFO, 1997)

Longline is another type of fixed gear used to target either pelagic or benthic species Bottom longlines are set on the sea floor with a mainline consisting of hundreds of baited hooks, called gangions. Each end of the mainline is anchored to the bottom, and marked at the surface with buoys and 'hi-fiyers' (Fig. 1.11). As a longline is retrieved the mainline becomes taut creating a 'clothes-line' effect across the bottom. Corals in the path of the longline will most likely be tilted, entangled, removed, or damaged during the retrieval process (Mortensen et al., 2005). This is particularly significant for large gorgonian corals that need to maintain an upright position. If a colony is damaged (e.g. branches severed) it may become more susceptible to parasitic organisms such as hydroids, or colonial sea anemones (Fig. 1.12), which has been observed inAtianlicCanada (Mortensenetal., 2005; Wareham & Edinger, 2007)

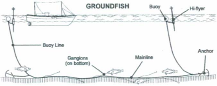

Figure 1.11. Illustration of longline gear configuration and components(DFO, 1997)

Figure 1.12. Photo of *Primnoaresedaeformis* skeleton encrusted wilh colonial sea anemones, hydroids and other organisms

It was surprising to find how frequently corals were captured byfixed gears in the Newfoundland and Labrador region (Wareham & Edinger, 2007). Thisismostlikelydue toa higher catchability of corals in certain areas that are targeted by fixed gear fishers Fixed gear fisheries operating on the sQuthwestGrand Bankstargetareasthatare considered 'untrawlable' such as steep canyon walls and areas withrockysubstrates These areas have not been impacted to the same degree as 'trawlable' areas, andasa result, will most likely have a greater abundance of corals and a greater chance of catching them

While both mobile and fixed bottom gears catch corals, the impacts of trawling pose the

benthic populations, communitystruclure, and habitats by remQvinglargemegafauna and altering physical components resulting in a lossofbiodiversityandhabitat complexity on a large scale (DFO. 2006)

In addition to bottom fishing practices, there are other threats to deep-sea corals, including: hydrocarbon exploration, bio-prospecting, scientific research surveys, ocean acidification, submarine cables, and aquaculture activities

1.2.2.1 HydrocarbonExploration

Hydrocarbon exploration has expanded since the 1980's in the Newfoundlandand Labrador region with three production fields operating on Grand Bank; Hibernia (1979), Terra Nova (1984),andWhite Rose (1984) oil exploration platforms (see oil fields in Fig 1.1). Exploration continues to expand with several projects underdevelopment

(Hebron/Ben Nevis, White Rose Extensions, Hibernia South Extensions and Garden Hill South; Newfoundland and Labrador, 2010). Hydrocarbon exploration is considered a threat to deep-sea corals through the discarding of fine drill mud, a by-product of the drilling process (Raimondi et al., 1997; Colman et al., 2005). These muds can accumulate near the platform or be transported futher away (e.g. up to 1 km) before settling (Neff, 1987) and are considered detrimental to suspension-feeders like corals because it can accumulate on polyps and inhibit feeding (Dodge et al., 1974; Dodge & Vaisnys, 1977; Dodge & Lang, 1983). While most research has been carried out on tropical corals, more recently *Lophelia pertusa* has been observed growing on oil platforms in the North Sea (Bell & Smith, 1999; Roberts, 2002; Gass & Roberts, 2006), **which would indicate that some species tolerate some degree of exposure to drill muds** HOW8ver, the North Sea platforms were not fixed to the ocean floor, therefore, colonies **were most likely isolated from drill cuttings which would have accumulated on the sea** f1oor. On the other hand, platforms like Hibernia are fixed to the seafloor, therefore may impact soft corals which are found on Grand Bank in the vicinity of the oil fields (Wareham & Edinger, 2007). The long-term effect of discarded drill cuttings on corals is

1.2.2.2 *Bio-prospecting*

Bio-prospecting is the harvesting of biological organisms for **scientific and commercial** purposes with the latter inciuding; production of pharmaceutical drugs (e.g. anti-cancer), cosmetics (e.g. face creams), nutritional supplements (S. Pomponi, Florida Atiantic University, personal communication, Dec. 5, 2005), and materials used in bone reconstruction (Ehrlich et al., 2006). Bio-prospecting poses a threat to deep-sea corals because it physically removes whole or parts of coral colonies from the sea floor: but more importantly there are no legal management regimes in place to regulate or police it in the deep-sea. Currently, there is no official bio-prospectingoccurring within the Newfoundland and Labrador region, which I am aware of

1.2.2.3 ResearchSurveys

A less-recognized threat to deep-sea corals is the destructive nature of bottom trawls, and dredges (Jennings & Kaiser, 1998) currently being used by DFO multispecies surveys. Duration of scientific trawls is relatively short (15 minutes) compared to commercial trawl sets (1-10 hrs) but continue to impact benthic environments. Modern soft-touch exploration technologies are available such as ROVs and have been used in Canada (Haedrich& Gagnon, 1991; Mortensenetal., 2000; Wareham, 2009a) Unfortunately, soft-touchresearchtoolsarecostty(i.e. operationalcosts, expertise), and funds are not readily-available

Department of Fisheries and Oceans Science Branches in Atlantic Canadahavefunded andcontinuetofunduniqueresearchopportunitiesutilizingaspecializeddeep-sea ROV, called Remotely Operated Patform for Ocean Science (ROPOS). Carrying out such scientific endeavours takes years to plan, but the outcomesare beneficial, with the abilitytocarryoutdiverse research ina variety of habitats inthe deep-sea (Bakeretal.,

1.2.2.4 *Climate Change*

Climate change includes global warming and ocean acidification. Global warming is caused by greenhouse gases released into the atmosphere. These gasses create a blanket effect, which cause global surface temperatures to rise includingmean-sea temperatures. Tropical corals are affected when sea temperatures rise toa point at which algae die off or 'bail out' from their coral host; this is knownascoralbleaching. In the absence of the algae, corals are no longer able to sustain themselves resulting in the eventual death 0l the coral colony (see Wilkinson, 2000). Fordeep-seacoralsthat require stable temperatures within specific ranges, even a slightchange in temperature at depth could pose a serious threat. It has been shown that such changes have begun and temperatures have risen at depths down to 700 m (Barnettetal., 2005). Tolerances of deep-sea corals to such temperature fluctuations are unknown

Ocean acidification is another threat to calcareous marineorganisms such as corals (Guinotteet al., 2006; Turleyetal., 2007).Itistriggeredbytherelease ollossil luel by-products (e.g. CO" SO" and NO,) and volcanic ash (CO,) into the atmosphere, which bond with water particles to lorm carbonic acid (H, CO_3), sulphuric acid (H, S04) and nitric acid (H, NO_3). These acids eventually precipitate out into the oceancausing pH levels to decrease and acidity to increase. Ocean acidity has already inc**reasedapproximately** 30% since the Industrial Revolution asa result of anthropogenic carbon released into the atmosphere (Caldeira & Wickett, 2003; Feelyetal., 2008). Adecreasein pH causes calcareous skeletons to erode and weaken, and as a result compromises the integrity of thesestructures(Feelyetal., 2004; Orretal., 2005; Hall-Spenceretal., 2008)

compostionbydecreasingtheoccurrenceofcalcareousorganisms likescleractinian corals and increasing sea-grass production (Hall-Spenser et ai., 2008). Il ocean **acidificationcontinuestorisethelong-termconsequences;** though unknown, are likely to amplify physiological stress's on deep-sea corals with similar**effects** as seen in shallow

Submarine cables are used for telecommunication purposes and are spread worldwide

a threat to deep-sea corals because off the direct damage caused during cable laying operations. However, few peer-reviewed scientificsludies havebeenwrittento determine the degree of impact these cables have on the deep-sea. One study has shown that submarine cables have a rninoreffect on deep-sea organisms and can provide a suitable hard substrate for attachment for some species such as sea anemones and soft corals (Koganetal.,2006). Most old cables are heavily colonized by sessile invertebrates and may be considered positive (Duncan, 1877;Wilson, 1979) Other studies are needed to determine how submarine cables impact other species of

1.2.2.6 Aquaculture

Newfoundland aquaculture operations use open-pen systems and are primarily based in Nortre Dame Bay, Bayd'EspoirandFortuneBay(FisheriesandAquaculture Newfoundland and Labrador, 2009). The aquaculture industry is expandingin Newfoundland and Labrador Region (e.g. salmon, shellfish) and maybeapotential

Newfoundland fiords (Haedrich& Ga9non, 1991). Aquaculture operations can impact benthic marine environments in several ways, from the pollution released into the sea as organic waste (Grant & Briggs, 1998; Ackefors & Enell, 1990; Hargrave et al., 1993), to the antifouling agents used on the cages which can leach toxicchemicals into the sea (Katranitsasetal.,2003). Accumulation of organic waste (e.g. fecalwaste,and unconsumed medicated feed pellets) directly below the pen can ereate anoxic conditions, and asa result reduce species diversity and biomass of benthic macrofauna (Ritzetal., 1989; Weston, 1990). Unconsumed medicated feed pellets can be hazardous as well when consumed by other benthic organisms (Grant & Briggs, 1998) Aquaculture in this region impacts primarilyshallowcoastalwaters; thereforeitisonly considered a theatto soft corals that are found inclose proximityto the aquaculture

Historically, deep-sea coral distributions in the northwest Atlanticweredocumentedin the 1800s at the time of the *Blake* (Agassiz, *1888), Challenger(Mo*seley, 1881), *Albatross(Verrill, 188S), andPrinceAlbertofMonaco(Jourdan*, 189S) expeditions. The Blake expedition surveyed the northeast United States, while the Challengerand Albatross expeditions surveyed as far north as the Scotian Shelf (Verrill, 188S; Agassiz, 1888). Only the Prince Albert of Monaco expedition (1887) sampledoff Newfoundland (Jourdan, 18gS). Duringthisexpeditionbenthicsamplesweretaken at two locations on

documented at a depth of 1267 m: *Caryophyllia communis, Vaughanella margaritata (Jourdan, 188S), F.alabastrum, Anthomastusagaricus(=A.grandiflorus?), Acanella normani(=A. arbuscula?)*. At Station 162(46°S0'6" N, Soo11'4S"W)onescleractinian *species, Desmophyllumdianthus, wasrecordedatadepthofat1SS* m(Jourdan, 189S) Refer to Figure 1.1 for map illustrating bathymetric features

On the Scotian Shelf off Banquereau Bank significant coral concentrationswerenoted by Captain Collins(1884), a prominent fishing skipper. He would name the area 'The

In the early 1900s, the *GodthaabExpedition(Kramp,* 1942)documentedalcyonarians, antipatharians, pennatulaceans, and scleractinians in the LabradorSea-BaffinBasin area from 54°00' N - 79°00' N. Most species were documented off southwest Greenland, withsomespeciesfrom Baffin Bay (e.g. sea pens and soft corals), andone soft coral was documented in the vicinity of Harrison Bank, offcentralLabrador(see Kamp, 1932)

Pax (1932) mapped five occurrences *ofStauropathesarclica(;Bathypathes); onesouth*

During the 1950s, corals were documented at several localities on the Grand Banksbya group of Russian scientists (Litvin & Rvachev, 1963; Nesis, 1963a; Nesis, 1963b). The first study generated maps of seabed topography and substrates of the Newfoundland-Labrador fishing areas (Litvin & Rvachev, 1963). Results mapped corals at the Stone

Flemish Cap, and southwest Beothuck Knoll (see Litvin & Rvachev, 1963)

The second study of the Russian expedition mapped the bathyal amphiboreal fauna of the Newfoundland-Labrador fishing area (Nesis, 1963a).Amphiboreal fauna are defined as species found in the Pacific and Atlantic *boreal* regions butnot in the Arctic. Three deep-sea coral species were documented along the continental shelf break off Newfoundland and Labrador, with other records from the Flemish Cap.Threespecies weredocumented; twolargegorgonians(i.e. Paragorgiaarborea*, Primnoa resedaeformis), and* one large sea pen (i.e. *Halipterisfinmarchica). Paragorgiaarborea* were mapped off Hawke Saddle, nose of the Grand Bank, Flemish Cap, and mouth of

Channel and on the southwest part of Flemish Cap. *Halipteris finmarchica* were documented on Flemish Cap, and on the southwest Grand Banks near Desbarres Canyon (see Nesis, 1963a). Samples consisted of by-catch from commercial trawls (n=539), Sigsbitrawls *(n=99)* and bottom grabs (n=164) from Atlantic Canada (Nesis,

Thefinal studyoftheRussianexpedition(Nesis, 1963b)produced maps of the benthos oftheNewfoundland-Labradorfishingarea. Paragorgiaarborea *andP. resedaeformis* weredocumentedbetween300-500monthenorthernpartof "GrandNewfoundland Bank" and the adjacent shelfbreak and slope. Many species of pennatulaceans(i.e *AnthoptilumgrandifiorumVerrill, 187g;PennatulaaculeataDanie*lssen, 1860; andP grandisEhrenberg, 1834) and one scleractinian cup coral (i.e. *F.alabastrum)were* documented between 250-500m in Laurentian Channel. Sea pens (i.e. *Halipteris finmarchica[=Pavonaria]Sars, 1851 ; andA.grandifiorum), gorg*onians(i.e. P. arborea, *K.ornata[=Ceratoisis], andR.gracilis), cerianthipatharians(i.e.S.arclica [=Bathypathes]), andhexacorals(i.e. F.alabastrum)weredocum*ented between 300-350 montheFlemishCap, break and slope (Nesis, 1963b)

In more recent years Tendal (1992) mapped new and existing recordsofP. arboreain the North Atlantic. Two new records were mapped on continental edge of Grand Bank, 14 on the Scotian Shelf,and 12 along the coast of Norway. Existing distributions were mapped off the southwestern (n=7) and southern (n=4) portions ofGreenland, aswellas alongtheReykjanesRidge(n=2), FaeroeIslands(n=5), andNorway(n=1; Tendal, 1992). Over a decade later, Tendal (2004) mapped thedistributi*onofStauropathes* arctica(=Bathypathes), anantipathariancoralfoundoffsouthwest Greenland adjacent to southeast Baffin Island, Canada. Intotal, hemapped 18 known occurrences; off

In Canada, advocacy for deep-sea coral protection began in the 1990s in southern Nova Scotiawhentwolocallonglinefishermen, Sanford Atwood and DerekJones, rallied to protect corals in an area known as 'Hell Hole', located between BrownsBank, in CanadianwatersandGeorgesBank, in United States waters (Breeze et al., 1997; Lees, 2002). It was known as an excellent fishing area with large underwater 'trees' and 'strawberry fields', later identified as gorgonians and soft corals. Together, the two fishermen formed the Canadian Ocean Habitat Protection Society, thefirstnon-profit organizationdedicatedtoconservingcoralsinCanada.Subsequently, they joined a team of scientists equipped with a ROV, leading the research team to the location of the first documented coral gardens in Canada (Lee, 2002)

Breezeetal. (1997) documented local fishers' knowledge on coral occurrences on the Scotian Shelf, along with distribution information from museum and scientific collections This information was compiled into the first map of coral distributions in Canada. Majority ofcoraloccurencesweremappedalongtheedgeandslopeoftheScotianShelf extending from Georges Bank to the Laurentian Channel

Macisaac et al. (2001) mapped the approximate locations of coral by-catch from opportunistic benthic surveys and experimental sites, as well as data collected from groundfish trawl surveys. Data was gathered primarily from theSeotianShelfwith sporadic occurrences mapped on the edge and slope of the LabradorShelf(i.e. Saglek Bank, OkakBank), Funk Island Bank, andonthenoseofGrandBank

Gass (2002) mapped coral distributions in the northwest Atlantic usingdatafrom; DFO research surveys, fisheries observers and Local Ecological Knowledge (LEK) from Nova Scotia and Newfoundland and Labrador fishermen. The majority of her findings were from the Scotian Shelf, with significant contributions from NewfoundlandandLabrador region (Gass & Willison, 2005). Coral occurrences were mapped along the edge and slope of the continental shelf extending from DavisStraitofsoutheastBalfinIsland, alongthe LabradorShelf(i.e.SaglekBank, Okak Bank, MakkovikBank,HamiltonBank), Northeast Newfoundland Shelf (i.e. Belle IsleBank, OrphanSpur, Tobin'sPoint), Grand Banks (i.e. nose, tail, southwestGrand Banks, Halibut and HaddockChannels), and Scotian Shelf (e.g. Stone Fence, The Gully, Misaine Holes, NortheastChannel, Jordan Basin). Wareham and Edinger (2007) used a similar methodology. However, a more **systematic approach was used and more complete fisheries observer data was** available, resulting in a greater number of samples callected and used in this thesis (see Wareham & Edinger, 2007; Wareham, 2009a)

Mortensen et al. (2006) mapped the distribution of deep-water coralsinAtlanticCanada using overlapping data sources similar to Gass and Willison (2005) but added; video surveys (see Mortensenetal., 2006), distributiondatafrom previous studies (Gass, 2002),datafrom literature sources (i.e. Zibrowius, 1980; Kramp, 1942; Madsen, 1994) and museum collections (e.g. Smithsonian, Atlantic Reference Centre,NovaScotia Natural History Museums). The majority of occurrences were mapped on the Scotian Shelfwith sporadicoccurrencesfromNewfoundland, Labrador, andsoutheast Balfin

Deep-seacoralsarelong-lived,slow-growinganimals(Roarketal., 2006). The largest species resemble underwater trees that can reach heights of several**metres(Mortensen** & Buhl-Mortensen, 2005). Fish utilize large corals as well as othercoralhabitatsas feeding areas, rest areas, juvenile fish habitats, and refuges from predation (Auster, 2005;Costelloetal., 2005). InNewfoundlandand Labrador, deep-sea corals are primarily found in areas of steep bathymetric relief primarily on the edge and slope of the continental shelf at depths > 200m (Nesis, 1963ab;Gass&Willison, 2005; Mortensenet al., 2005; Wareham & Edinger, 2007; Wareham, 2009a). A suite of environmental **variablesinfluencecoraldistributions: temperature, strongc**urrents, and suitable substrates (Nesis, 1963b; Cinbergetal., 1981; Bryan & Metaxas, 2006; Mortensen et al., 2006). Manyquestionsstiliremainunansweredconcerningtherelative importance of

Deep-sea corals are ecologically-important because theycreate habitats for other marine organisms as large individuals oras large concentrations (Austeret al., 2005; Buhl-Mortensen & Mortensen, 2005; Auster, 2007; Etnoyer & Warrenchuk,2007; Moore etal., 2008;Bakeretal., 2008). Whiletherearenumerousthreatsto deep-sea corals, the impact of bottom fishing gears; particularly trawling, is considered to be the greatest threat(Probert, 1997; Watling&Norse, 1998; Fossaetal., 2001; Hall-Spenser et al.,

2005; Stone, 2006). However, changes in oceanic systems from global warming and ocean acidification are now being documented and potentiallyha**vesignificant** consequencestocoralsandothermarinelife(Feelyetal., 2004; Orretal., 2005; Hall-

Explorations conducted in the late 1800's provided reports on deep-seacoral distributions in the northwest Atlantic. Observation advQcacyby local fishers from Nova Scotia provided the impetus for scientific studies of corals (LeeS,2002), leadingtowell-studied distributions on the Scotian Shelf(Breezeetal., 1997; Maclsaacetal., 2001; Gass&Wiliison, 2005). A significant outcome of this research hasbeenthe establishmentofthreeimportantareasfordeep-seacoralprotection; *The Gully Marine ProlecledArea(DFO, 2004a),NorlheastChannelCoralConservationArea* (DFO, 2002), and *Lophelia[Stone Fence]CoralConservalionArea(DFO*, 2004b). These protection zones will be discussed in more detail in Chapter 4

In the case of Newfoundland and Labrador region, distributions ofdeep-sea corals have beendocumentedbyearlyexploratoryexpeditions(1800's), andby preceding studies (1963-2006). The next two chapters present geographic and bathymetric distributions (2003-2007) of deep-sea corals within the northwest Atlantic focusingonNewfoundland,

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2 DISTRIBUTION OF DEEP-SEA CORALS IN THE NEWFOUNDLAND AND LABRADOR REGION, NORTHWEST ATLANTIC OCEAN

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Deep-sea corals were mapped using incidenlal by-catch samples from stock assessment surveys and fisheries observations. Thirteenalcyonaceans, two antipatharians, foursolitaryscleractinians, and 11 pennatulaceanswererecorded Coralswerebroadlydistribuled along the continental shelfedgeand slope, with most species found deeper than 200 m; only nephlheid soft corals were foundonlheshelf. Largebranchingcoralswithrobustskelelonsincluded*Paragorgiaarborea(L., 1758), Primnoaresedaeformis(Gunnerus, 1763), Keratoisisornata(Verr*ill, 1878), *Acanthogorgiaarmata(Verrill, 1878),Paramuriceaspp., andlwo* antipalharians. Coral distributionswerehighlyclustered,with most co-occurring withotherspecies. Scientific survey data delineated two broad coral species richness hotspots: southwest Grand Bank (16 spp.) and an area oflhe Labrador slope between Makkovik Bankand Belle Isle Bank (14 spp.). Fisheriesobservationsindicatedabundantordiverse corals off soulheastBaffinlsland, CapeChidley, Labrador, Tobin'sPoint, andtheFlemishCap Corals on the Flemish Capcomprisedexciusivelysoftcoral, sea penS, andsolitary scleractinians. Most coral-rich areas were suggested inearlierresearch based on stock

assessment surveys or Local Environmental Knowledge (LEK). Currently there are no

Deep-sea corals can be found worldwide (Freiwald & Roberts, 2005),butuntilrecently data on their distributions in the Atlantic Ocean were limited (Collins, 1884; Deichmann,

al., 2001; Gass & Willison, 2005; Watling & Auster, 2005; Mortensen et al. 2006). Within thelastdecade, knowledgeofcoralsineasternCanadahasincreaseddramatically, with attention being primarily focused on the Scotian Shelf (Breeze etal.,1g97; Maclsaacet al., 2001). The continental shelf and slope of Newfoundland and Labradorhavereceived very little attention (Nesis, 1963;Tendal,1992;Gass&Wiliison, 2005). This study presents deep-sea coral distribution patterns and diversity datainanareathathas, up to now, received only exploratory treatment

In Atlantic Canada deep-sea corals have beenfoundatdepths>20Om primarily along the continental shelf edge and continental slope, particularly near submarine canyons or saddles where the shelf has been incised (Breezeetal., 1997; Maclsaacetal., 2001; Gass & Willison, 2005; Mortensen & Buhl-Mortensen, 2005b). Such bathymetricfeatures are considered good habitat for corals because they are associated with strong currents that winnow away tine sediment, exposing harder substrates, and provide a reliable source of fine particulate organic maUer for suspension feeding corals (Hecker et al., 1980; Harding, 1g98). Conversely,increasedsedimentationcanbehazardoustocorals, congesting polyps and inhibiting feeding processes (Heckeret al., 1980). Hard substrates are believed to be important especially to largergorgonian corals such as *P. resedaeformisandP.arborea; twospeciesthataretypicallyf*oundattachedto al., 2006). Olhercoralshaveacalcareousholdfaslforanchoringinsoftsediment(e.g., *AcanellaarbusculaJohnson*, 1862). Many solitary scleraclinians such as *Flabellum alabastrum(Moseley*, 1873) simply lay on the ocean floor, while 0thers (e.g., *DesmophyllumdianthusEsper*, 1794)usuallyretainaholdfast

Deep-sea corals are slow growing and long lived (Lazierelal., 1999; Andrewsetal., 2002; Risketal., 2002; Roarketal. 2005; Sherwoodelal., 2006), and can reach heights upt03m(Miner, 1950; Tendal, 1992; Breezeelal., 1997; Mortensen& Buhl-Mortensen, 2005). Large corals increase complexity of benthic environments through their arboreal growth and robust skeletons (Krieger & Wing, 2002); in turn thesestructurescan creale habitat for other benthic organisms during someslages oflheir life history (Ausler, 2005). Large sessile organisms, however, are more susceptible 10 anthropogenic disturbances,especiallyfishinggearincontactwilhtheoceanfloor (Watling & Norse, 1998; Krieger, 2001 ; Fossaelal.,2002; Hall-Spenceretal.,2002; Thrush & Dayton, 2002; Anderson &Clark,2003). The Northeast Newfoundland Shelf, soulhern Labrador

trawling, (Kulka & Pitcher, 2002). As shelf stocks were depleted, fishingeffortshiftedto deeper waters on the slope, wilh potentiallysevere consequences for deep-water ecosystems(Koslowetal., 2000)

The goal of this chapter is to map the distribution and diversity of deep-sea corals off the coastsofNewfoundland, Labrador, andsoutheaslBaffin Island usingincidentalby-catch from scientific surveys and fisheries observations aboard commercial vessels. General information on the distribution paUernsofdeep-sea coralsandtheir diversity in the region is limiled, andlheextenttowhich they have been impactedbyfishingactivitiesin the Newfoundland and Labrador region is unknown. This study pres**entsdistributions** and depth ranges of individual coral species and highlights areas with high diversity and

The study area in questlon encompasses the continental shelf and slope of the Grand BanksofNewfoundland,NortheastNewfoundlandShelf,FlemishCap,LabradorShelf. DavisStrait, andBaffinBasin. Itisourhopethatthisworkwilladdto the growing information on deep-sea corals (Cairns & Chapman. 2001 ; Gass&Willison. 2005; Mortensenetal., 2006)andprovidenecessarydatatohelpconservecoralhabitatinthe

Coral data was gathered opportunistically from three sources. commencing in 2002 up to andinciudingMay2006. TheCanadianDepartmentofFisheriesandOceans (DFO) Multispecies Stock Assessment Surveys covered central and southernLabradoraswel1

Northern Shrimp Stock Assessment Survey. co-sponsored by the Northem Shrimp

Labrador. Observations from the Fisheries Observer Program (FOP) were the third SQurceofdata, and cDvereda broader area, extending from Baffin Basin to the Grand Banks and Flemish Cap. Each data sDurceencompassed different managementzones and incorporated slightly different sampling techniques. Therefore. each source is

2.3.1 Multispecies Stock Assessment Surveys and the Northern Shrimp survey

Department of Fisheries and Oceans multispecies stock assessment surveys (2002-2006) consisted of an annual spring and fall survey aboard theCanadian Coast Guard Ship (CCGS) *Wilfred* Templeman. and the CCGS *Teleost.* Survey tows followed a random stratified survey design and covered NAFO (Northwest AtlanticFisheries Organization)divisions2HJ (southern Labrador), and 3KLMNOP(northeast-southern Newfoundland, and The Grand Banks) (see McCallum &Walsh, 1996). The CCGS

conductedbothshaliowanddeepwatertows<1,500m. ResearchVessels(RV) used in the study were equipped with a Campelen 1800 shrimp trawl with rockhopper footgear tight rubber disks (102 x35 em diameter) with spacers along thefootrope. The16.9m wide net had four panels constructed of polyethylene twine: wing panel 80 mm mesh

mesh size with a 12.7 mm liner in the cod end (c!. McCallum &Walsh, 1996). Tow duration was 15 min. at 3 kt. (± 1 kt.); average tow length was 1.4 km (0.79 n.m.), and tows were conducted along a consistent depth contour. The area swept was calculated by multiplying net wing span by tow distance for an average swept area per tow of 0.025 km' (0.0073 n.m.'). The total area that can be surveyed byDFO peryearforaliNAFO divisions in the region was 690,676 km'. However, not all NAFO divisions were surveyed each year: divisions 2J and 3KLNOPweresurveyed in each year from 2002-2005,but not consistently; divisions OB and 2G were surveyed in 2005; division 2H was surveyed in 2004. Eachcatchwassampledforfishspecies, andsub-sampledfor invertebrate by-catch. Individual coral species were assigned a numericalcadewith the exception of pennatulaceans, which were grouped. All suspected corals were assigned a species code, bagged, labeledwithlocatornumber, andfrozen. Departmentof Fisheries and Oceans technicians and scientific crew were provided with coral identificationguides produced by the Bedford Institute of Oceanography and the authors. Training workshops for DFO crew and fisheries observers were organized byin 2004 and 2005 by the author. All specimens were forwarded to Memorial University (MUN) and identified by the authors using gross morphology (shape, size, hardness, colour, and

[redacted]

[redacted] assumed lobe almoslalways recovered bylhe RVlechnicians, and lack of coralsina given set was interpreted as absence of coral in that sample

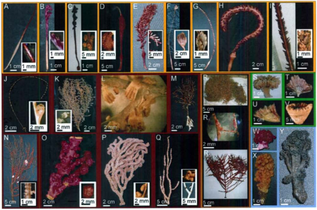

Figure 2.1. Deep-sea coral specimens collected off Newfoundland, Labrador, and Baffin Island. OrderPennatulacea: A.) *Distichoptilumgracile;* B.) *Pennatulaphosphora; C.)sea pensp. 6(?);D.)Penntulasp.(?); E.)Pennatulagrandis;F.)Umbellulalindahli;G.) Halipteris finmarchica;* H.) *Anthoptilum grandiflorum;* I.) *Funiculina quadrangularis*. Order *Alcyonacea: J.)Radicipesgracilis; K.)Acanthogorgiaarmata; M.) Acanellaarbuscula; N.)Paramuriceaspp.(?);P.)Primnoaresedaeformis; Q.)Keratoisisornata; L.) Anlhothelagrandiflora; O.) Paragorgiaarborea; W.)Anthomastusgrandifiorus; X.) Gersemia rubiformis;* Y.) *Capnella florida*. R.) Order Anlipatharia (?). Order Scleractinia S.) *Desmophyllum dianthus;* T.) *Flabellum alabastrum;* U.) *Dasmosmitia lymani;* V.) *Vaughanellamargaritata. Note:(?) =speciesnot confirmed*

2.3.2 Fisheries Observer Program

Fisheries observers are deployed aboard Canadian and foreign fishing vessels and are responsible for monitoring compliance to fisheries regulationsand for the collection of scientific and technical data related to fishing operations (Kulka&Firth, 1987). Fisheries managers and scientists use these data to manage and studyfisheries. Observersare deployed in most fisheries in the region covering a broad array of depths extending from Baffin Basin to southern Newfoundland and Flemish Cap. Prior to coliectingcorals, all observers were equipped with the same identificationguidesastheRVtechnicians, and participated in coral identification workshops in 2004 and 2005 organized by the authors Coral data were collected between April 2004 and May 2006. Observercoverageatsea variedbetweenO-100% dependingonthefishery, quotaaliocation, gear type and NAFOdivision. Sampling protocol required each observer to submitat least one sample of each coral speciesencQuntered on each trip, and to record all other occurrences of each coral species on set/catch data sheets. Samples and records were tracked to assess accuracy of data from each observer. Coral distribution data from fisheries observers presented here include identified samples and records that could be compared with an identified sample previously submitted by the individual observer reporting the record. Data from fisheries observers had several limitations. First, distribution data from observers were biased by fishing effort. Second, unliketheRV surveys, observercoraldatawerenotstandardizedforvariations in tow length, gear type, and search time. Finally, observers may not have had sufficientsearchtimeto locate all coralswithinacatch, especiallyin high volume fisheries such as shrimp. Given these limitations, observer data were treated as presence, butnotabsence, of coral

2.3.3 Definition of Coral Species Richness Hotspots and Abundance Peaks

Coral species richness hotspots were identified qualitativelyinthescientificsurveydata as areas with higher species richness per tow than surroundingsets. Observerdata were not used to identify coral species richness hotspots, but wereused to describe the range of individual species, and to characterize coral distributions in areas not covered by the scientific surveys

2.3.4 Mapping of Deep-sea Coral

Data from research surveys (Multispecies and Northern Shrimp Surveys). and samples and records from observers were combined into a master database and mapped in MapInfo Professional 8.0 Software. Bathymetry data was provided by General Bathymetric Chart of the Oceans (GEBCO. 2003). Distribution maps were verified visually for accuracy and crosschecked with data points plotted onCanadian Hydrographic Service bathymetry charts. Any discrepancies were investigatedand adjusted appropriately

2.4.1 MultispeciesstockAssessmentsurveysandNorthernshrimpsurvey

Thirty-five research surveys carried out between December 2002 andJanuary2006 wereexplored:2002(1), 2003(2), 2004(10). 2005(1g). and2006(3). Thirty-four multispecies surveys yielded 1.968 tows from NAFO divisions 2HJ and 3KLMNOP. One Northern Shrimp Survey yielded 227 tows from NAFO divisions OB and 2G. The total area swept was 52.75 km', or approximately 0.00685% of the survey area. NAFO divisions 3Pn (2002 only) and 3Ps (2005 only) were the onlydivisions within the region in which surveys covered > 0.01 % of area within the time frame of this study. One area wasnotadequatelysurveyed, a small area adjacent to Hudson Strait in the Labrador Sea (-61·20'N, 63·00'W). II was excluded because oflhe high probabilityofgear damage due to rough substrates and the reported concentrations 0f large gorgonians (e.g., P. arborea, P. *resedaeformis)* found in thisparticulararea(D. Orr, DFO, personal communication, Oct. 2006). In total, 976 coral specimens were collected from 622 scientific survey sets that caplured al least one coral specimen perset.SeeTable2.1 fora summary of each species frequency, mean depth and range: Notenephtheidsoft corals are represented by *Capnellaflorida, Gersemiarubiformis*,**andatleastoneother** forrnofnephtheid, which has yet to be identified. *Paramuriceapla*comusandP. grandis maybothberepresented, spiculemountssuggestpresenceofbothspecies, butsome specimensarenotyetdetermined. Stauropathesarcticaisconfirmed,buttheidentityof a second growth form ofanlipatharian assigned *Bathypathessp.*, has not yet been determined, partlyduetouncertaintyinthetaxonomyofthisgroup. Sea pens4, 6, and 12 arelhree distinct forms yet to be identified; sea pen spp. refers to pennatulaceans too poorly preserved 10 be idenlifiable beyond order

Order	Family	Species	Coral Frequencies (#)				Mean Depth & Ranges (m)		
			RV	FOPs	FOPr	Total	RV	FOPs	FOPr
Alcyonacea	Alcyoniidae	*Capnella florida* (=*Duva*)	284	118	97	499	444 (47 - 1404)	615 (230 - 1287)	552 (269 - 1087)
		Gersemia rubiformis	166	31	111	308	174 (41 - 722)	286 (51 - 1249)	547 (56 - 1249)
		Neptheids (?)	88	3	-	91	253 (67 - 1398)	717 (399 - 1135)	-
		Anthomastus grandiflorus	49	15	1	65	913 (171 - 1404)	834 (302 - 1277)	821
	Primnoidae	*Primnoa resedaeformis*	11	6	11	28	402 (162 - 676)	559 (357 - 1157)	432 (380 - 592)
	Paragorgiidae	*Paragorgia arborea*	8	10	9	27	573 (370 - 846)	719 (448 - 1277)	481 (402 - 576)
	Anthothelidae	*Anthothela grandiflora*	2	-	-	2	723 (528 - 918)	-	-
	Isididae	*Keratoisis ornata*	6	8	16	30	491 (195 - 664)	786 (302 - 1100)	879 (403 - 1262)
		Acanella arbuscula	81	50	187	318	822 (154 - 1433)	827 (344 - 1277)	893 (302 - 1244)
	Acanthogorgiidae	*Acanthogorgia armata*	30	19	25	74	873 (171 - 1415)	819 (278 - 1260)	513 (302 - 1207)
	Chrysogorgiidae	*Radicipes gracilis*	11	4	13	28	1052 (785 - 1337)	997 (384 - 1491)	981 (419 - 1207)
	Plexauridae	*Paramuricea grandis*	22	16	11	49	810 (152 - 1415)	800 (457 - 1193)	594 (402 - 773)
		Paramuricea placomus							
Antipatharia	Schizopathidae	*Stauropathes arctica*	2	14	21	37	1075 (1013 - 1136)	1027 (745 - 1287)	1069 (872 - 1228)
	Antipathidae	*Bathypathes* sp.							
Scleractinia	Flabellidae	*Flabellum alabastrum*	53	19	69	141	819 (218 - 1433)	629 (353 - 1135)	833 (339 - 1200)
	Caryophylliidae	*Dasmosmilia lymani*	1	-	-	1	457	-	-
		Desmophyllum dianthus	-	2	-	2	-	883 (713 - 1052)	-
		Vaughanella margaritata	1	3	-	4	1320	1199 (1163 - 1252)	-
Pennatulacea	Halipteridae	*Halipteris finmarchica*	29	11	336	577	749 (113 - 1433)	745 (344 - 1028)	669 (182 - 1244)
	Pennatulidae	*Pennatula borealis* (=*grandis*)	16	16			876 (488 - 1404)	633 (320 - 1018)	
		Pennatula phosphorea	36	9			823 (96 - 1345)	713 (146 - 1223)	
		Pennatula aculeata	1	-			229	-	
	Funiculinidae	*Funiculina quadrangularis*	18	-			1018 (346 - 1433)	-	
	Kophobelemnidae	*Kophobelemnon stelliferum*	1	1			1235	1154	
	Ombellulidae	*Umbellula lindahli*	4	3			463 (145 - 620)	870 (723 - 984)	
	Protoptilidae	*Distichoptilum gracile*	2	2			921 (794 - 1048)	750 (346 - 1154)	
	Anthoptilidae	*Anthoptilum grandiflorum*	47	19			796 (171 - 1433)	833 (320 - 1072)	
		Sea pen sp. 4 (unidentified)	2	-			647 (493 - 801)	-	
		Sea pen sp. 12 (unidentified)	2	-			1224 (1135 - 1313)	-	
		Sea pen spp. (unidentified)	3	18			775 (212 - 1200)	697 (277 - 1063)	
Total coral specimens			976	397	907	2281	RV = DFO Multispecies Research Surveys (2003-2006) & Northern Shrimp Research Survey (2005)		
Total sets sampled			2192	45 566		47 758			
Total sets with at least one coral specimen			622	864		1477	FOPs = Fisheries observations, samples submitted (2004-2006)		
Total sets without corals			1581	44 702		46 281	FOPr = Fisheries observations, records with no samples (2004-2006)		

From January 2004 to May 2006 fisheries observers documented 1,304 coral occurrencesfromnineofthe25directedfisheriesoperatingintthe region: 397 occurrences were from submitted samples and 907 were from records only (Table 2.1) The Greenland halibut (turbot; *Reinhardtiushippoglossoides* Walbaum,17g2)fishery had the highest frequency of coral by-catch (n = 677) and fished the deepest depths (averagedepths889-1070mdependingongeartype)onthecontinental slope (Table 2.2). Fishing effort was concentrated in deep waters off the south-eastern slope of the Baffin Island Shelf, southeast Labrador slope, the Northeast Newfoundland Shelf, and in a deep water trough on the Northeast Newfoundland Shelf called Funk Island Deep (see Chapter 1, Fig. 1.1 for bathymetric features). Mobile gear used in this fishery included Otter trawls (1 net) and twin trawls (2 nets), with the main difference between these being the number of nets hauled per vessel. Fixedgearwasalsoused, bottomlongline andgillnet, but mainly off the southwest Grand Bank,inareasunsuitablefortrawling

The northern shrimp *(Pandalusborealis* Kroyer, 1838 and P. *monlagui* Leach, 1814) fishery had the second highest frequency of coral by-catch(n =226) with effort concentrated on the Labrador Shelf edge (average depths 349-41 5mdependingon gear type; Table 2.2). Three trawl types were utilized: shrimp, twin, and triple trawls Mandatory Nordmore Grate by-catch reduction devices (22 mm - 28 mm bar spacing) were used in conjunction with each gear type to help reduceby-catchofmobilespecies Thegrateallowsshrimptopassthroughandintothenet,whileoversizedby-catchare redirected out through an exit door in Ihetop panel of the net

Both the shrimp and Greenland halibut fisheries deployed multiple gear types but only thelatterusedbothmobileandfixedgearclasses.Overall,mobile gear captured 943 coral occurrences (samples and records), comparedto 3630ccurrencesbyfixedgear (Table 2.3). The Otter Trawl had the highest frequency of coral by-catch(n;636)ofall gear types. Other fisheries in the region captured corals as weiland are summarized in Table 2.2. Further analysis of coral by-catch patterns among directed fisheries and gear types will be published separately

Table2.2.Summaryofcoralfrequenciesbytargetfishery, geartype, andaverage depthsfished; datafromfisheriesobservationsdocumentedbetween April 2004 and January 2006. Note: GN;gillnet, LL;longline, CP = crab pot, OT = Ottertrawl, ST;

Target Species	Fixed		Average Depth Fished (m)	Corals Captured (#)
Skate *(Raja* spp.)	GN		439	2
White hake *(Urophycis tenuis)*	GN		218	6
Redfish(Sebastessp.)		OT	447	189
Yellowtail flounder *(Limanda ferruginea)*		OT	165	18
Atlantic halibut *(Hippoglossushippoglossusl*	LL		867	56
Snow crab (Chionoecetes *opilio)*	CP		399	128
Angler, monkfish *(Lophiusamericanus)*	GN		331	2
			891	429
Greenland halibut *(Reinhardtiushippoglossoides)*	GN		995	140
	LL		1070	27
		TT	889	81
Shrimp *(Pandalusborealis*, P. *montagw)*		ST	415	102
		TT	349	111
		TTT	365	13
				1304

Table 2.3. 5ummary of coral frequencies by species, targetfishery, gearclass, and gear type; data from fisheries observations documented between April 2004 and January 2006. Note: GN = gillnet, **LL** = longline, CP = crab pot, OT = Otter trawl, 5T = shrimp

	Gear Fixed	**Types per coral**			frequency Mobile			
Capnella florida	32	4	2	74	63	40	-	215
Gersemia rubiformis	72	21	1	26	16	6	-	142
Neptheids	-	1	-	1	1	-	-	3
Anthomastus grandiflorus	-	2	8	4	1	1	-	16
Primnoa resedaeformis	-	1	-	2	14	-	-	17
Paragorgia arborea	-	2	1	10	6	-	-	19
Keratoisis ornata	-	-	21	3	-	-	-	24
Acanthogorgiaarmata	2	3	12	27				44
Radicipesgracilis		6	9	2				17
Paramuriceaspp		1	1	18				27
Antipatharia	-	14	1	17	-	3	-	35
Flabellum alabastrum	-	6	3	56	-	22	1	88
Desmophyllumdianthus		1	1					2
Vaughanella margaritata		3						3
Pennatulacea	1	41	16	296	1	48	12	415
5ubtota1	128	150	85	636	102	192	13	1304
Total		363			g43			

2.4.3 Deep-Sea Coral Distribution and Diversity Patterns

Twenty-eight deep-sea coral species were identified in the region**, withtwoadditional** forms represented that have not been identified to species level. In total there were 13 alcyonaceans, two antipatharians, four solitary scleractinian**s,and11 pennatulaceans** (Table 2.1; Figs. 2.1 &2.3)

The order Alcyonacea was subdivided into three informal groups: soft corals with polyps contained in massivebodies, gorgonianswitha consolidatedaxi**$, andgorgonians** without a consolidated axis (Bayer, 1981). 5eeFigure2.2foralcyonaceandistributions

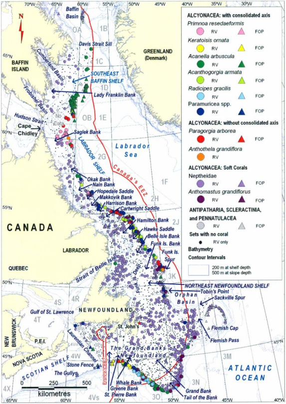

Figure 2.2. Distribution of alcyonaceans in scientific surveys (RV) 2003-2006 and fisheries observer data (FOP) 2004-2006

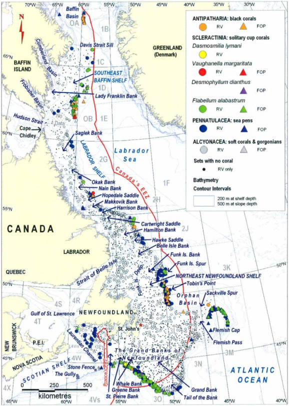

Figure 2.3. Distribution of pennatulaceans, solitary scleractinians, and antipatharians in scientific surveys (RV)2003-2006 and fisheries observer data (FOP)2004-2006

Soft corals consisted of one alcyoniid *(AnthomastusgrandiflorusVerrill,1878)*andat least two nephtheids *(Gersemiarubiformis* Ehrenberg, 1834; C*apnellafioridaVerrill,* 1869), however, athirdnephtheidspecieswassuspected. Because of uncertainty in identifyingnephtheidcoralstospecies, allnephtheidsweremappedasasinglegroup

Nephtheids(n= 898) had the highest frequency of all speciesdocu*mented.Gersemia* rubiformis(Fig. 2.1X), wastheonlyspeciesinthestudythatwasconsistentlydistributed on the continental shelf(n =308). Depth for this species ranged between47-1 ,249m **with average depths < 174 m. Individual colonies were < 5 em high (when frozen and contracted),hadawiderangeofcolourvariations, andwerefrequentlyobserved** attached to pebbles, broken shells, and live gastropods

Capnella florida (Fig. 2.1Y)was mostly found in deeper waters on thecontinentalshelf edge and slope (n = 499). However some samples were captured in shallower waters on the shelf. Depth for this species ranged between47-1,404mwithaveragedepths> **444 m. Individual samples were massive bodied colonies < 15 em high, with multiple** branches that terminated in clusters of non-retractable polyp**s.Coloniesweremostly** black with some variations of brown and beige. Attachedsubstratesconsistedofmostly rockandgravel, butsomecolonieswereobservedattachedtolivegastropodsand

Anthomastus grandiflorus (Fig. 2.1W) was found only on the shelf edge and slope of the

Newfoundland(n=65). The depth of this species ranged between 171-1,404mwith average depths> 821 m. Most individual colonies, when contracted, were < 5 cm high characterised bya capitulum that had long polyp tubes and large polyps extended from the cap. Individual colonies were supported byasterile basalstalk that was observed attachedtopebbleandcobblesubstrates.Onejuvenilespecimen was observed

Seven species ofgorgonianswith a consolidated axis were recor**ded:*Acanella*** *arbuscula,Acanlhogorgiaarmala, Paramuriceaspp.(P.placomusL.andP.grandis* Verrill *1884),Primnoaresedaeformis, Keraloisisornata,andRadicipes gracilis* (Verrill, 1883). Most of these species have large (>30 cm)fan-like skeletonswiththeexception of A. *arbusculaandR. gracilis,* which were usually smaller

Acanella arbuscula (Fig. 2.1M)had the highest frequency of all gorgonians(n=318) with concentrations on the shelf edge and slopeofsoutheastBaffinIsland, Hawke Channel,Funk Island Spur, and southwest Grand Bank (Fig. 2.2). Depth of this species ranged between 154 - 1,433 m with average depths> 822 m. Individual colonies were usually < 15cmhigh, red, bush-like, andsupportedbyadistinctlybandedstem with calcareous root-like base. Polyps were located atoppositeanglesonbrittlesegmented **branches. Colonies were usually damaged and captured in multiples with several tows** acquiring50-100individualcoloniespertow

Acanthogorgia armala (Fig. 2.1K)had the second highestfrequencyofthisgroup(n= 74)withconcentrationsoff:southeastBaffinIsland, HawkeChannel, Tobin'sPoint, and southwestGrandBank.Depthforthisspeciesrangedbetween171-1,415mwith averagedepths>513m. Individualcolonieswere <50cminheight, characterised by dense yellow-beige branches with long narrow polyps that have crown like tips. Many sampleswerecQvered with juvenile gooseneck barnacles, and seallops. Aswell,two samples were attached to two separate K. *ornata* colonies

Paramuricea samples are believed to beP. *grandisbased* on spicul**eanalysis,butP** placomusmayalsobepresent(Fig.2.1N).Whengrouped,Paramuriceaspp.hadthe thirdhighestoccurrenceofthisgroup(n=49),withmostoftheseconcentrated on the continental slope off the LabradorShelf- NortheastNewfoundland Shelf, andthe continental slope off the southwest Grand Bank. One sample was captured as far north as the Hudson Strait and a second sample was captured as far south as the tail of the Bank. Depth for this genus ranged between 152 -1 ,415 m, with most samples recovered at averagedepths>594m. Individualcolonieswere flexibleandfan shaped in one plane, and ranged from 20-85 cm in height. Polyps were short, round, and compressed to the branch. All specimens were black with the exception of one v**ividorangesample** photographed-1 hr. aftercapture(Fig. 2.1N). Samples were seldom observed with a substrate attached even though holdfastswere present. Several sampleswereattached tocobblesandonesample(50cmtallfan)wasfirmlyattachedtoalargesubfossilK *ornata* base. The age of this *K. ornata* colony was likely to be several centuries, based on known growth rates of *Keratoisis* sp. from the family Isididae(Roarketal., 2005)

Primnoa resedaeformis (Fig. 2.1P), for the most part, were not widely distributed (n = 28). Most were found off Saglek Bank, with five other samples documented on the north

162 - 1,157 m with average depths> 402 m. Two specimens on Saglek Bank were captured at depths of 162 mand 165m; the remaining colonies occurred at slope depths **down to 1,157 m. Individual colonies were < 35 em in height and were characterized by** dense downward-directed yellow or pink polyps covering a rigid dark brown skeleton Cross sections of the stem revealed concentric growth ringsalterna**tingbetweencalcite** andgorgonin (Andrewsetal., 2002; Sherwoodetal. 2005). FoursubfossilP *resedaeformis* skeletons were not mapped, the largest being ~ 35 cm from the base to the truncated tips of the branches

Keratoisisornata(Fig.2.1Q)wasonlyfoundonthesouthwestGrandBank(n=30)

between 195 - 1,262 m with average depths> 491 m. Individual colonies were < 50 em with the majority of the samples submitted being either fragments of the original colony or large masses that were severely damaged in trawls. The skeletons are rigid and characterized by thick white calcified brancheswithproteinaceousinternodes.Polyps ranged in density from thick mats to sparse polypsona predominantly bare skeleton One rare intact sample, captured bylonglinegear, had manyassociated species encrusted on the axis or attached among the branches. Mostnotable species were the ***solitaryscieractinianD.dianthus,gorgonianA.armata,andnumerousjuvenilelceland***

Radicipesgraci/is(Fig.2.1J)weredistributedonthesouthwestGrandBankonly(n= 28). Depth of this species ranged between 384-1,419mwith averagedepths>981 m Individualcolonieswere <80cm in height and consisted ofasingle coiled or twisted iridescent axis. Polyps were sparse but evenly spaced on the ste**mandtheentirecolony** was supported bya calcareous root-likeholdfast

The final group belongin9 to thealcyonaceans is the gorgonians that lack a consolidated **axis.** ***TWQspeciesweredocumented: ParagorgiaarboreaandAnthothelagrandiflora*** (Sars, 1856). *Paragorgiaarborea(Fig.* 2.10)(n = 27) were clustered in an area adjacent

sporadically distributed off Cape Chidley, Funk Island Spur, and the Grand Bank slope Depth of this species ranged between 370-1,277mwithaveragedepths >481 m. Most samples were small, fragmented pieces « 25 em); no whole intact colonies were collected. Polyps were usually retracted inside bulbous branch tips. Samples were red, yellow-beige or salmon coloured. One particular set from the northern shrimp survey captured 50 kg of *P. arborea* from an area adjacent to the Hudson Strait (61°22'N, 61°10'W). The subsample was forwarded to DFO and consisted of a large laterally compressed midsection of the main stem (25 cm in length and 11 em in diameter) and several branch tips. *Anthothea grandiflora* (Fig. 2.1L) had only two small samples submitted from RV surveys; one sample from off Cape Chidley, Labrador at 528 m and a second sample from the Funk Island Spur at 918 m. Both samples were identified using polyp morphology and sclerite descriptions (cf. Verseveldt, 1940; Miner, 1950)

The order Antipatharia (Fig. 2.1R1) was represented by two species, *Stauropathes arctica* (LÜtken *1871*), and probably *Bathypathes* sp. (S. France, University of Louisiana, personal communication, Dec. 2006). The majority of the samples were from observers with only two samples from scientific surveys (Fig. 2.3). Antipatharians were widely distributed on the continental slope in deep waters from Baffin Basin to southwest Grand Bank (n= 37). Three clusters emerged: southeast Baffin Basin (north of Davis Strait Sill), southeast Baffin Shelf (south of Davis Strait Sill), and on the southwest slope of the Orphan Basin (Tobin's Point area). Depth of this species ranged between 745-1,287 m with average depths> 1027 m. Two growth forms were observed among samples: S *arctica* (*Pax*, 1932; Opresko, 2002) with an open-branched skeleton (Fig. 2.1R2), and a compressed 'tumbleweed-like' form referred to as *Bathypathes* sp. (Fig. 2.1R). The largest antipatharian recorded was 45 em long x 30 em wide x 15 cm high specimen of the tumbleweed form, captured at 1,013 m off Flemish Cap

The order Scleractinia was represented by four solitary cup corals: *Flabellum alabastrum*, *Desmophyllum dianthus*, *Vaughanella margaritata* (*Jourdan*, *1895*), and *Dasmosmilia lymani* (Pourtal,;s, 1871). Cup corals were distributed along the continental shelf edge and slope with concentrations off the southwest Grand Bank and southeast Baffin Island (Fig. 2.3)

Flabellum alabastrum (Fig. 2.1T) distributions were clustered off the Southeast Baffin Shelf, FlemishCap, andsouthwestGrandBank(n=141). Toalesserextent, other

Shelf. Depth ranged between218-1 ,433mwithaveragedepths > 629 *m.Flabellum alabastrum* samples were identified by the corallum and compressed calice (cf. Cairns, 1981). *Vaughanella margaritatasamples* (n = 4) were documented off the Southeast Baffin Shelf and east of the Hopedale Saddle. Depth of this species ranged between 1,163 -1 ,320 m with average depths > 1,199 m. Three samples with multiple specimens oflivingandsubfossilV.margaritatapersample, werecapturedbybottomgillnets targeting Greenland halibut off the Southeast Baffin Shelf. Onespecimen, missing a holdfast, was captured ina *RV* survey east of the Hopedale Saddle (Fig. 2.1V)

Desmophyllum dianthus (Fig. 2.1S) samples were submitted only by observers (n = 2) Both samples were from the southeast Grand Bank; one sample was captured at 1,052 m by bottom gillnet gear and the second sample, which was attached to a *K. ornata* colony,wascapturedat713mbylonglinegear.Inadditionone subfossilspecimen, not included in the dataset, was captured by a gillnetat 1,125m offthe Southeast Baffin Shelf. *Dasmosmilia lymani* (Fig. 2.1U) was only documented once off the southwest slopeofGrandBank(44"52'N, 54"23'W)at457m. Allscleractinianswereidentifiedby grossmorphologyofthecorallum, andconfirmedbyDr. StevenCairns, of the

TheorderPennatulacea(Fig. 2.1A-I)wasrepresentedby11 species of sea pens. Nine were identified; two have yet to be identified to the species level. Pennatulaceanswere distributed along the edge of the continental shelf east of BaffinBasin, offsoutheast Baffin Island, Tobin'sPoint, Flemish Cap, and the southwest Grand Bank(n = 577; Fig 2.3). The greatest diversity of sea pens was found nearsouthwestGrandBank. Species were found at depths between96-1,433m. Individual colonies varied in size between 10-80cm. Specimens were identified bypeduncie, rachis, and polyp morphology (cf Williams, 1995; *1999).Anthoptilumgrandiflorum(Verrill, 1879; Fig.1H),andPennatula phosphora(L.;Fig.2.1B)werethemostabundantfoliowedbyHalipterisfinmarchia* (Sars, *1851),Funiculinaquadrangularis(Pallas*, 1766), and *Pennatulagrandis* (Ehrenberg, 1834; Table 1). Numerous samples of *H. finmarchia* were observed with commensal sea anemones *Stephanaugenexiiis(Verrill,* 1883) firmly attached to the rachis(cLMiner, 1950). Samples that were damaged beyond identification to genus, were grouped as "sea pen spp.", as were observer records of sea pens

Based on maps of scientific survey data, two coral species richness hotspots were identified (Fig. 2.4-2.6). The first hotspot (Fig. 2.5) was situated on the Labrador continentalslopebetweenMakkovikBank(55°30'N, 57°05'W)andBelleIsleBank (52°00'N, 51°00'W). Thesecondhotspot(Fig.2.6)was locatedoffsouthwest Grand Bank and tail of the Bank (- 42°50' -45°1O'N, 49°00' -55°00'W). Both areas had higher species richness per tow than sets surrounding them and higher**frequenciesofscientific** survey stations containing corals than surrounding areas. Southwest Grand Bank and tail of the Bank had the greatest species richness (16 spp.),with ninealcyonaceans, five pennatulaceans, and twQ scleractiniansrecorded. Makkavik Bank-Belle Isle Bank hotspot (14 spp.) had sevenalcyonaceans, fourpennatulaceans,**twQscleractinians, and oneantipatharianrecorded.Speciesrichnesspertowbasedonsci**entific survey data ranged between zero and **11** species per set with only two sets capturing nine or more

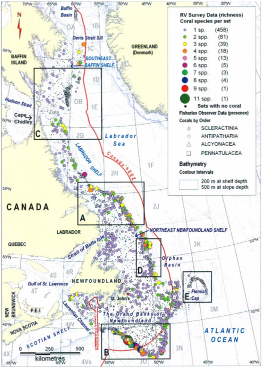

Figure 2.4. Coral species richness per set in scientific surveydata. Mostspecioseareas were; A} Makkovik Bank-Belle Isle Bank, and B.) southwest Grand Bank. Distribution of coral rich areas from DFO survey data and fisheries observer data: C.) Southeast Baffin Shelf-CapeChidley, D.) FunkIslandSpur-Tobin'sPoint, andE.) Flemish Cap

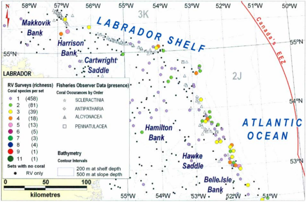

Figure 2.5. Coral species richness per set in scientific surveydata and coral occurrences by Order from fisheries observer data for Makkovik Bank-Belle Isle Bank Hotspot

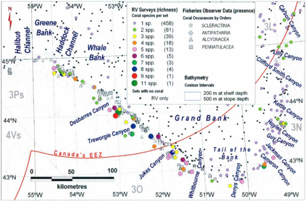

Figure 2.6. Coral species richness per set in scientific survey dataandcoraloccurrences by Order from fisheries observer data for southwest Grand Bank and tail of the Bank

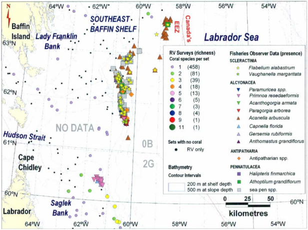

Figure 2.7. Coral species richness per set in scientific surveydataand coral occurrences by species from fisheries observer data for Southeast Baffin Shelf -CapeChidley

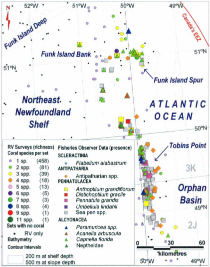

Figure 2.8. Coral species richness per set in scientific surveydata and coral occurrences by species from fisheries observer data for Funk Island Spur-Tobin'sPoint

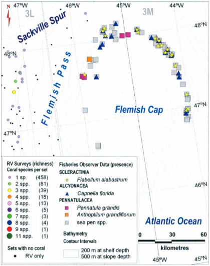

Figure 2.9. Coral species richness per set in scientific survey data and coral occurrences by species from fisheries observer data for Flemish Cap

Distribution maps presented contribute to the growing knowledge of deep-sea coral distribution and diversity of Newfoundland, Labrador, and southeast Baffin Island Thirteen alcyonaceans, two antipatharians, four solitary scleractinians, and 11 pennatulaceans were documented. Corals were more widely distributed on the continental edge and slope than previously thought, but only nephtheids were found on top of the shelf. Only ahermatic corals were identified with nooccurrence of the reef building *Lopheliapertusa(L.), asreportedattheStone* Fence, Scotianmargin(Gass& Willison, 2005; Mortensen etal., 2006). This study documented hundreds more unique records than previously known, and with much more complete and systematic data coverage than was previously available. Many of the coral-rich areas in this study were identified previously by Gassand Willison (2005). Their results partially overlapped with the findings presented in this study off Cape Chidley, NortheastNewfoundlandShelf,

2.5.1 Distribution of Hotspots

Coral species richness hotspots were identified in two distinctlocations(Figs. 2.5&2.6) The hotspot on the southwest Grand Bank and tail of the Bank had the greatest species richness with 16 coral species documented. The topographyofthis area is complex with steep slopes, and numerous canyons. The area is most likely influeneed by warm Labrador slope water (Haedrich & Gagnon, 1991). Previous reports from fisheries observers and local fishers indicated thepresenceofcoralsinthis region, but very little data from scientific surveys had been documented (Gass & Willison, 2005; Mortensen et al., 2006). Thesecondhotspotextendedalongthecontinentalshelf edge and slope of the Labrador Shelf from Makkovik Bank to Belle Isle Bank. It spanned thegreatestarea and included 14 coral species. Most corals were concentrated on the shelfedge and slope with someneptheid soft corals on the bank tops. *Acanellaarb*usculaandsoft corals were the most abundant species, as both dominated the Funk Island Spur along with several species of sea pens (Le., A. *grandiflora*, P. *phosphorea, andP.grandis)* Rare species were documented in this area, with one occurrence af A. *grandifloraofflhe* Funk Island Spur at918m and one occurrence of V. *margaritataat* 1,320moff HopedaleSaddle. Jourdan (1895) reported that *V.margaritata*

Cape Chidley, based on only one year of survey data. This area was not identified as a biodiversity hotspot in the current analysis, but recent unpublisheddataandpastreports suggest high coral abundance and intermediate coral biodiversity. HighdensitiesofP *resedaeformis* were documented off Cape Chidley by Macisaac et al. (2001) and Gass and Willison (2005). The area immediately east of Hudson Strait (-61 °20'N, 62°30'W), wasnotsurveyed, norwasobserverdataavailable.Nonetheless, the largest samples submitted for this study were collected from the outer edges of this area with many large **gorgoniansdocumented, primarilyPrimnoaresedaeformisandP*aragorgiaarborea*** (Gass&Willison, 2005). Sets from the 2006 Northern Shrimp Survey 2006 captured up t0500kgofcoral, mostlyP. resedaeformis andP. arboreaina singletowwithinthis area (Wareham etal., 2010). The Hudson Strait region is influencedbystrongcurrents and high nutrient flows from both the Labrador Current and Arcticwatersdrainingfrom the Hudson Strait (Drinkwater & Harding, 2001). Observer samplesand records of A *arbusculawere* most numerous off Southeast Baffin Shelf. This area is intensively fished

andfishers' LEKwere previously documented off southeast Baffin Island (Davis Strait) and Cape Chidley(Macisaacetal., 2001 ; Gass & Willison, 2005)

Tobin's Point, off the Northeast Newfoundland Shelf is intensivelyfishedforGreenland halibut, shrimp, and snow crab *(Chionecetesopilio* Fabricius, 1788). The coral species reported there were dominated by *Capneltaflorida,* sea pens, andantipatharians Flemish Cap had mostlytheneptheid C. *florida,* sea pens, thescleractinianF. alabastrum, andoneantipatharian. NumerousA.grandifiorus(n=541), possible juveniles, were documented on the northeast side of the Flemish Cap (Wareham, 2009) but were not documented within the time frame of this study. Flemish Cap was not covered by Canadian scientific surveys, so coral distributions were derived from observer data only. The clustering of corals on the north side of Fiemish Cap may be an artefact of fishing effort, which was concentrated on it's smooth north side. The south sideisdeeplyincisedbycanyons, makingildifficultlerrainfortrawling;thesouthsideof thecapmaycontainsuitablehabitatforavarietyofcorals, buthas had relatively little sampling effort to date. In general the top of banks had the lowest coraldiversilywith only nephlheids present. Most corals are probably incapable of colonizing the top of banks due to limited hard substralesandcold lemperaluresatshallowerdepths in this location (cf. Mortensen etal., 2006)

2.5.3 Substrates of Coral Biodiversity Hotspots and Other Areas of In**terest**

Information on surficial geology has been sparse and limited toSov**ietfishing** investigations by Lilvin and Rvachev(1963),andhighlygeneralized maps of surficial geology of the conlinenlal margin ofeaslern Canada focusing onthe bank-tops (Fader & Miller,1986; Piperelal., 1988).Subslralesforeachholspotandolherareasofinteresl

The Grand Banks of Newfoundland (Grand,Whale, Green,&St. PierreBanks) are relativelyshallowandareheavilyinfluencedbywaveaclion.Sand dominates the bank top, wilh gravel, shell beds and muddy-sand patches lhroughout(Fader&Miller, 1986) Theedgeandslopearea veneerofAdlophousSandsandGravels. Substratesonthe slope progressively change with depth from sand-mud to mud (Litvin&Rvachev, 1963;

Flemish Cap and Flemish Pass are located in inlernationalwatersjusteastofGrand Bank. Flemish Cap isa dome shaped plateau ranging from *150-350m* deep. Cap

mud and boulders on lheslope; mud is predominant al slopedeplhs > *1000* m(Lilvin&

Rvachev, 1963). FlemishPassisa 1,200 m deep trou9h that separates the FlemishCap from the Grand Bank. Flemish Pass is strongly influenced bytheLabradorCurrent Substrates in Flemish Pass consist mostly of sandy mud with some pebbles and stones (Litvin & Rvachev, 1963). The Northeast Newfoundland Shelfincludes Funk Island Bank, Funk Island Spur, and Tobin's Point. Substrates abruptly change from sand on top of Funk Island Bankat-300m, tosandy-mudontheslopeat-SOOm, tomudoffFunk Island Spur at >1000 m (Litvin & Rvachev, 1963). The Labrador Shelf extends along the

troughsupt0600mdeepdividetheshelfintobanks(Piperetal., 1988). Sand substrates dominate southern bank tops with scattered pebbles andgravel; slope composition changes rapidly with depth from muddy-sand to sandy-mud to mud. Hawke

sandy-mud on the saddle slope towards the shelf edge (Litvin & Rvachev, 1963). There is little information available on slope substrates north of Harrison Bank on the Labrador

2.5.4 Comparison with Local Ecological Knowledge

Many of the coral areas identified byfishers' LEK(Gass &Willison,200S)were confirmed with scientific survey and observer data in the current stu**dy.Nonetheless,** several important differences emerged. First, current data suggest there are much more **continuQuscoralhabitatalongthesQuthernLabradorslope, withagreatervarietyof** corals than indicated from LEK. Second, thesouthwestGrand Bank and tail of the Bank hotspot, identified in the current study as an area of high species richness and coral record density, was much less prominent in LEKdata orin previouslyavailablescientific survey data. These discrepancies between studies maylargelybea result of more complete scientific survey sampling efforts throughout the Newfoundland and Labrador region. In the current study the lack of large gorgonian records on the southeast Grand Bank, andtherelativescarcityofP. arboreasamplesmayrefiectloss of corals due to trawling impacts. Evidence of deleterious effects on deep-sea corals by mobile fishing gear (e.g., trawls) has been published in detail (Watling & Norse, 1995;Auster& Langton, 1gg9; Fossaetal., 2002; Hall-Spenceretal., 2002; Anderson&Clark, 2003), mostlyfocusingontheeffectsoftrawlingondeep-seascleractinians, with limited atlention to impacts on deep-sea gorgonians(Krieger, 2001; Mortensenetal., 2005, Stone, 2006). In the current study, mobile gears captured more corals than fixed gears **and, ingeneral, CDveredlargerareas. Thedurationoftrawltowsrangedbetweenone** and 10 hr. / tow, thus making the precision of coral localities from observer data highly variable. Allhoughthedeep-sea coral clusters recognized byfishers have persisted despite a long history of intensive deep-water trawl fishing inthe region (see Kulka & Pitcher,2002), there is litlle information on changes in abundancesofdeep-seacorals through time (Gass & Willison, 2005)

A variety of sessile invertebrates were observed growing commensally on deep-sea

invertebrate diversity of corals (Buhl-Mortensen & Mortensen, 2005), samplesfromfixed gear (e.g., longline andgillnet) have contributed manyintactcoral assemblages, or groups of coral living together. For example, two colonies of A. *armata* were found to be attached totwoseparateK. *ornata* colonies, one of which also included the scleractinian D. dianthus. AnotherK.ornatasamplehadjuvenilecoloniesofA.*grandi(forus* and A *armata* attached. Many observations of gooseneck barnacles, scallops, **seaanemones,** and echinoderms, all in juvenile stages, were attached *toK. ornata*. Manynephtheidsoft corals were observed attached to living gastropods. Theseobservationssuggestthat hard substrates may be limited in some areas, and emphasize the important contribution that large corals can make lowards creating and slrucluring deep-sea habitat, including habitat for other deep-sea corals. The nature of associations between corals and fish are difficult to determine in trawl survey data because fish and coralsmayhaveco-occurred in the same habitatwithoul any direcl biological inleraction(Edingerelal., 200l)

The findings reported here complemenl earlier work (Gass & Willison, 2005), and provide specific information on deep-sea coral distribution anddiversityintheregion However, caution must be exercised when interpreting these results for two reasons First,thedala resulted from only three years of sampling, wilh 0nly one year of scientific sampling in northern Labrador and lheDavis Slrait-with sampling gaps in scienlific data. Second, the distribulion dala from fisheries observers werebiasedbyfishingeffort Coral conservation is a fairly new concept in eastern Canada. Three areas with unique features including very high densities of corals or unique speciesoccurrenceswere established on the Scotian margin 10 help prolectcorals: the NortheastChannelCoral Conservation Area (2002), the Slone Fence Lophelia reeffisheriesclosure(2004), and The Gully Marine Protected Area (2004; Breeze & Fenton, 2007). Coralsin Newfoundland and Labrador waters are generally widespread along the continental edge and slope. Hence a network of representative areas would bethe most appropriate conservalion approach (cf. Fernandesetal., 2005)

Twenty-six ahermatypic deep-sea corals were identified offNewfoundland, Labrador, and southeaslBaffin Island; four coral species, mostly seapens, areyetlobeidentified Corals were widespread along the conlinental edge and slope, withonlynephtheids occurring at shelf depths. Two regions of coral hotspotswithhighspeciesrichnesswere identified using scientific survey data. When fisheries observer data were used in conjunction with survey data, other areas with high coral occurrencesemerged,butmay have been biased by distribution of fishing effort. All areas identified in this study, with the exception of Flemish Cap, were previously identified byfishers' LEK, butspecies composition and diversity results differed between current surveydataand LEK. Results emphasize the validity and valueoffishers' LEK in identifying areaswithhigh concentrationsofcorals(cf.Breezeetal., 1997; Gass&Wiliison, 2005). Currently there

Labrador, and Baffin Island regions. Based on widespread coraldistributions, a representative areas approach should be applied toward conservation of corals and

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3 UPDATES ON DEEP-SEA CORAL DISTRIBUTION IN THE NEWFOUNDLAND, LABRADOR, AND ARCTIC REGIONS, NORTHWEST ATLANTIC

Published as Wareham, V.E. (2009). Updates on deep-sea coral distributions in the Newfoundland Labrador and Arctic regions, northwest Atlantic. InK. Gilkinson, &E Edinger (Eds.), *The ecology of deep-sea corals of Newfoundland and Labrador waters biogeography, life history, biogeochemistry, andrelationtofishes*. (pp.4-22). *Canadian*

New data collected by the Department of Fisheries and Oceans from Newfoundland, Labrador, and eastern Arctic partially filled data gaps on deep-sea coral distributions identified in Wareham and Edinger (2007). All coral frequencies increasedwith36 species mapped: 14alcyonaceans, twoantipatharians, six solitary scleractinia**nS, and 14** pennatulaceans. Insituobservationscoliectedby RemotelyOperated Vehicle (ROV) documented new records, unique habitats consisting of high coral abundances, and provided evidence of coral damage caused by fishing. Therearet**hreeinterimprotection**

Fisheries Organization Coral Protection Zone on southwest Grand Banks, Narwhal-Coral Protection Zone in Canada's eastern Arctic, and a Voluntary Coral Pro**tectionZonein** Hatton Basin off northern Labrador. Newly established closures are a good first step but permanent designation is needed to provide long-term protection and to protect unique

In Canada, distributions of deep-sea corals have now been extensively mapped in the northwest Atlantic (Gass & Willison, 2005; Wareham & Edinger, 2007) although only a small fraction of the seabed has been surveyed and mapped. Understanding corals and their inter-relationships with other species in deep-sea ecosystems is crucial in order for the Department of Fisheries and Oceans Canada (DFO) to meet conservation objectives under the *Fisheries Act* and *Oceans Act*. Coral data played a key role in the establishment of Sable Gully as Atlantic Canada's first Marine Protected Area (MPA; DFO, 2004a) under the Oceans Act. Additional fisheries closures in the Maritimes region were established on the basis of coral hotspots in the Northeast Channel (DFO, 2002) and Stone Fence (DFO, 2004b)

In Newfoundland and Labrador no official protection exists for corals (e.g. MPAs), **however several preliminary measures have been taken. There are two interim closures** in the Newfoundland and Labrador region, and one in the Arctic. The first is an industry led Voluntary Coral Protection Zone, a 12,500 km^2 area in NAFO division 2G-OB off Cape Chidley, Labrador (MPA News, 2007). It was initiated and implemented by industry comprised of the Groundfish Enterprise Allocation Council (GEAC), Canadian Association of Prawn Producers (CAPP) and Northern Coalition (NC). The purpose of the closure is to conserve specified species of large corals (e.g. ***Primnoa resedaeformis*** **Gunnerus,** *1763, Paragorgia arborea Unnaeus, 1758, Paramuricea placomus* **Linnaeus,** 1758 and *P. grandis* Verrill, 1883, and antipatharian spp.) in significant concentrations that are known to exist in the area (B. Chapman, Canadian Association of Prawn Producers, personal communication, Sept. 2005). The second, CAD-NAFO Coral Protection Zone, is a mandatory closure on the slope of the Grand Bank in NAFO division 30 between 800 - 2000 m (NAFO, 2007). It was initiated by the Canadian-NAFO

Working Group and implemented by NAFO. The purpose of the closure is to protect coralsfoundintheareaand 'freezethefootprint'offishingactivities in deeper waters

OA (DFO, 2007). It was initiated and implemented by DFO in April 2006, in order to protect Narwhal over-wintering grounds and deep-sea corals

This chapter provides an update on the ongoing process of identifying and mapping deep-sea corals in the northwest Atlantic, building on the existing dataset initiated by Wareham and Edinger(2007)inordertohelpidentifyandhighlightareas for protection withintheNewfoundland, Labrador, andArctic regions. Theupdate focuses on the time period covered by the International Governance Program (IGP; 2005-2007)

3.3.1 5tudyArea

The study encompasses the continental shelf, edge, and slope of the Grand Banks of Newfoundland (NAFO divisions 3LNOP), Flemish Pass (NAFO division 3L), Flemish Cap (NAFOdivision3M), NortheastNewfoundlandShelf(NAFOdivision3K), LabradorShelf (NAFOdivisions2GHJ), SoutheastBaffinShelf(NAFOdivisionOB),and Baffin Bay (NAFOdivision OA). See Figure 3.1 for overview of study area

Data was collected opportunistically from two primary sources; (i)annualmultispecies research surveys conducted by the Science Branch Newfoundland andLabradorRegion (2006-2007), DFO,and(ii)fisheriesobserverdatacollectedonboard commercial fishing vessels operating within the NAFO Convention Area (2006-2007)

In addition, DFO Central and Arctic Region began contributing coral distribution data in 2006 from multispecies research surveys conducted in the Arctic (NAFOdivisionsOAB) All data (2006-2007), including representative coral samples, wereforwarded to the DFO Newfoundland and Labrador Region and incorporated into the existingdatabase

Multispecies research surveys conducted by DFO Newfoundland and Labradorin2000 (one survey in NAFOdivision 3L)and 2004 (two surveys in NAFOdivisons2J, 3KLNM) collected corals from the Newfoundland and Labrador region but sampleswereoriginally sent to Bedford Institute of Oceanography, DFO Maritimes Region. All samples were returned to DFO Newfoundland and Labrador Region and the data are now incorporated

The dataset contains only one research survey from the Northern ShrimpStock Assessment Survey (2005): a five year annual survey in progressforthe Arctic region (2005-2010), co-sponsoredbytheNorthernShrimpResearchFoundationandDFO Newfoundland and Labrador. Two additional research surveys were conductedin2006 and 2007; however this data was not available during this time

Research survey vessels follow a standardized stratified random sampling protocol. In Newfoundland and Labrador, surveys use a Campelen 1800 shrimp trawl with rockhopper footgear (McCallum & Walsh, 1996). For arctic surveys two gear types **with** rock hopper footgear are used; Cosmos 2600 shrimp trawl for shallow water tows (100-800 m) and Afredo otter trawl for deep water tows (400 - 1500 m) (T. Siferd, DFO Central and Arctic Region, personal communication, May, 23, 2008). Fisheries observer datawascollectedfromavarietyofmobileandfixedgeartypes. For further details on samplinggear,andmethodologiesseeChapter2(WarehamandEdinger, 2007)

In July2007, high resolution video collected bya deepwater ROV(ROPOS) provided *in siluobservations* of corals at three deep water sites in Newfoundland and Labrador; HalibutChannel, HaddockChannel, andDesbarresCanyon. Dataconsists of high resolution video, frame grabs, and still images that are currently beingprocessed (Baker etal.,2008)

fisheries observers) as well as the type of habitats from which the data was collected For example, survey trawls can only sample relatively level sea bedsleadingtoabias in favour of certain types of sea floors-favouring level grounds and excluding steeper slopes and canyons (e.g. Grand Bank continental slope and edge). On the other hand,

fishing grounds' based on past catch rates and the level of experienceofthevessel's skipper. Observer data incorporates many fisheries using different gearciasses (mobile andfixed), geartypes(shrimptrawl,twin trawl),andfish in all types of marine habitats (canyons) on a variety of substrates (e.g. boulder fields, mud, or sand). In short, research data can be biased towards 'trawlable' bottomtypes, whereas observer data can be biased towards 'fishing effort'

Results are presented as coral distribution maps building on baselinedatacompiledby Wareham and Edinger (2007). New data includes; coral samples from 2000-2005 (Newfoundland and Labrador) that were not originally included in Wareham and Edinger (2007), multispeciessurveydatafrom2006-2007 (Newfoundland, Labrador, and Arctic regions), fisheriesobserverdatafrom2006-2007 (Newfoundland, Labrador, and Arctic regions), and preliminary results from ROPOS Discovery Cruise 2007 (Newfoundland and Labrador). Maps are broken down byoverali sampling effort (Fig. 3.1)foliowedby coral distributions based on sub-groups; antipatharians(Fig. 3.2), alcyonaceans[large gorgonians(Fig.3.3), smaligorgonians(Fig. 3.4), andsoftcorals (Fig. 3.5)], scieractinians(Fig. 3.6),pennatulaceans(Fig. 3.7),andROPOS highlights (Fig. 3.8) Voucher specimens of all pennatulaceans were sent to and verified by Dr. G. Williams of the California Academy of Sciences. Scleratinianswere identified by Dr. Stephen Cairns of the Smithsonian Institute (Cairns, 1981).Chrysogorgiaagassizii(Verrili, 1883) was identified using Cairns (2001). See Table 3.1 fora summary of data frequencies documented and mapped during the course of the project

Table 3.1. Summary of coral frequencies used in distribution maps

Group		Wareham and Edinger (2007)		
		134	78	212
Alcyonacea	small gorgonians	422	502	924
	soft corals	963	1481	2444
		148	130	278
Pennatulacea		577	1060	1637
Total		2281	3315	5596

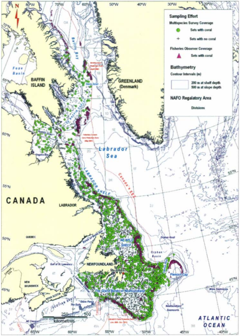

Figure 3.1. Study area and sampling effort with distribution of deep-seacorals highlighted. Data was collected from; Northern Shrimp Survey (2005), Newfoundland and LabradorMultispeciesSurveys(2000-2007), Arctic Multispecies Surveys (2006-2007), and from fisheries observers aboard commercial fishing vessels(2004-2007)

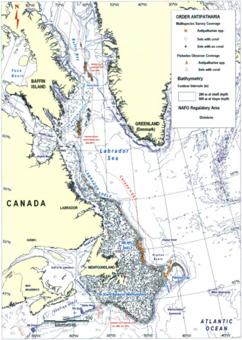

Figure 3.2. Distribution of deep-sea corals from the DrderAntipatharia(includes *StauropathesarcticaLutken, 1871 , andBathypathesspp*.}. Data was collected from; Northern Shrimp Survey (2005), Newfoundland and Labrador MultispeciesSurveys (2000-2007). Arclic Multispecies Surveys (2006-2007). and from fisheriesobservers aboard commercial fishing vessels (2004-2007)

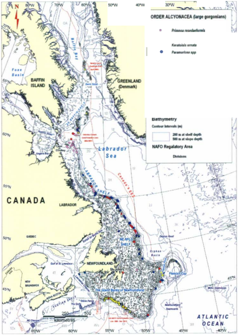

Figure 3.3. Dislribulionofdeep-sea corals from the OrderAlcyonacea(large gorgonians). Dalawascoliecledfrom;NorthernShrimpSurvey(2005), Newfoundland and Labrador Multispecies Surveys(2000-2007), Arctic Mullispecies Surveys (2006-2007),and from fisheries observers aboard commercial fishing vessels (2004-2007)

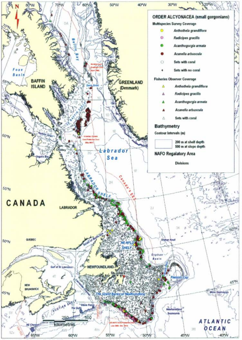

Figure 3.4. Distribution of deep-sea corals from the OrderAlcyonacea(small gorgonians). Data was collected from; Northern Shrimp Survey (2005), Newfoundland Labrador Multispecies Surveys (2000-2007), Arctic Multispecies Surveys (2006-2007), and from fisheries observers aboard commercial fishing vessels (2004-2007)

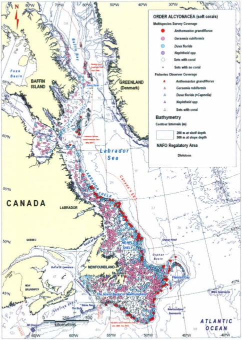

Figure 3.5. Distribution of deep-sea corals from the OrderAlcyonacea(softcorals). Data was collected from; NorthernShrimpSurvey (2005), Newfoundlandand Labrador Multispecies Surveys (2000-2007). Arctic Multispecies Surveys (2006-2007),andfrom fisheries observers aboard commercial fishing vessels (2004-2007)

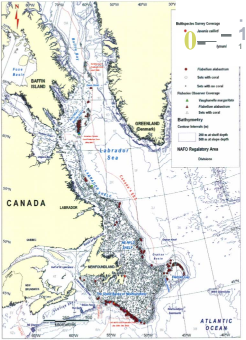

Figure 3.6. Dislribution of deep-sea corals from the OrderScieractinia (solitary stony corals). Data was collected from; Northern ShrimpSurvey(2005), Newfoundlandand Labrador Multispecies Surveys(2000-2007),Arctic Multispecies Surveys (2006-2007), and from fisheries observers aboard commercial fishing vessels{2004-2007)

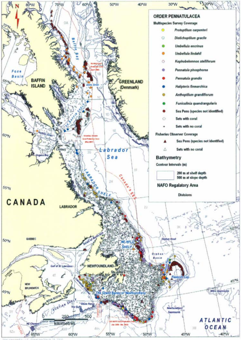

Figure 3.7. Distribution of deep-sea corals from the Order Pennatulacea(seapens) Data was collected from; NorthernShrimpSurvey(2005), NewfoundlandandLabrador Multispecies Surveys(2000-2007),Arctic MultispeciesSurveys (2006-2007),andfrom fisheries observers aboard commercial fishing vessels (2004-2007)

Preliminary Results ROPOS Discovery Cruise 2007

Preliminary results from the 2007 ROPOS Discovery Cruise include the locations of unique coral habitats (Fig. 3.8) and five species not previous documented in this region New species records include lwo pennatulaceans *(Umbelfula encr;nus* Linnaeus, 1758; *ProtoplilumcarpenteriK6l1iker, 1872), onegorgonian(Chrysogorgi*aagassiziiVerrill, 1883), and two scleractinians *(FlabellummacandrewiGray,* 1849; *Javaniacailler;* DuchassaingandMichelotti,1864; Fig. 3.9)

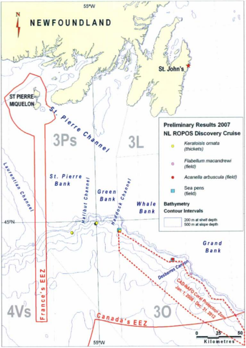

Figure 3.8. Preliminary results of unique deep-sea coral habitats from Newfoundland and Labrador ROPOS Discovery Cruise (2007) including clusters of *Keratoisis ornata* colonies, termed 'thickets', and large concentrations of sea pens and *Acanella arbuscula*

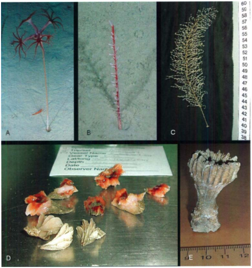

Figure 3.9. Deep-sea coral species documented in Newfoundland andLabradorduring *Ihe2007ROPOSDiscoveryCruise; A.)Umbellu/aencrinus; B.)Proloplilumcarpenleri; C.)Chrysogorgiaagassizii; D.)Flabellummacandrewi, andE.)Javaniacailleli*

In total 36 species of coral have now been documented in the Newfoundland, Labrador, and Arctic regions including; 14alcyonaceans, twoantipatharianS, sixscleractinians, and 14pennatulaceans

Newfoundland, LabradorandArcticdeep-seacoraldistributiondata presented here have contributed to filling in data-gaps identified by Wareham and Edinger (2007). Areas such as the continental edge and slope of Northeast Newfoundland Shelf, OrphanBasin, and Flemish Pass are now represented. Arctic data from DFOCentral and Arctic Region represents a valuable contribution by extending samplingcDverage into far northern regions, which include frontier areas, including BaffinBay, Davis Strait, Hudson Strait, and Ungava Bay. However, a significant gap still exists on the boundarylinebetween NAFOdivisions2G-OB. This area remains insufficiently sampled based on only one year ofresearchdata(Wareham&Edinger, 2007). Itisnotedthatanadditional two years of data exist but were unavailable for analyses (Northern Shrimp Survey2006-2007). This area,HudsonStrait-CapeChidley(alsoknownasHattonBasin), has been identified in **previausstudiesasanimportantareaforcorals, notablyParagorg*iaarboreaLinnaeus,*** 1758 and *Primnoa resedaeformis* Gunnerus, 1763 (Maclssac et al., 2001 ; Gass & Willison, 2005; Mortensenetal., 2006; Edingeretal., 2007; Wareham&Edinger, 2007), two species not found in *any* great abundance within the study area. Part of the Hudson Strait-Cape Chidleyarea has temporary protection within the industry initiated Voluntary Coral Protection Zone (MPA News, 2007)

The 2007 ROPOScruise provided unique non-destructive sampling opportunities including extensiV8 video footage and photographs of corals, and unique coral habitats in HaddockChannel, HalibutChannel, and DebarresCanyon (Fig. 3.8). Healthy and damaged coral colonies, notably the long-lived species *K. ornata* (Sherwood & Edinger, 2009) were recorded on video in Haddock and Halibut Channels. This cruise also provided insight into other unique habitats not previously see**nintheregionsuchasK** *ornata* thickets, sea pen fields, and A. *arbusculafields*

In general, major patterns of deep sea coral distributions recorded by Wareham and Edinger (2007) slill hold true wilh lhe majority of corals distribuled along lhe continental edge and slope except for a few oddities

- an antipatharian was documented allhe mouth of Strail of Belle Isle and on the north side Flemish Cap (Fig. 3.2)
- *Keratoisis ornata* was documenled in Flemish Pass with a high abundance of juvenile samples in both sets. Subfossilized samples of *K. ornata* were
- *Primnoa resedaeformis* occurrences (juvenile samples only), were documented on top of the Labrador Shelf and Grand Bank (Fig. 3.3)

Overall, there was an increase in frequencies of occurrence for all species (Table 3.1) Notably, antipalharians, a deep water group usually found aidepths > 1000m (Wareham & Edinger, 2007), appear to be more widely distributed lhan originally recorded (Tendal, 2004; Gass & Willison, 2005; Wareham & Edinger, 2007). This is most likely a result of sampling effort from multispecies surveys carried oulin 2007, which focused on deep-waler areas in Flemish Pass and the Northeasl Newfoundland Shelf Fisheries observer data also recorded higher occurrences as weil, most likely due to commercial fishing effort targeting deeper waters where the chanees of encountering corals would be higher

The newly established inlerim closures, described in lhe introduclion, are a good first step bul stronger permanenl legislation is urgently needed to fully proteclcorals from anthropogenic disturbances. The urgency is due to the fact that corals are highly sensitive to bottom fishing disturbances, and *are* impacted even on the first initial tow (Kreiger, 2001). This was especially evident on May 23, 2007 when a fisheries observer documented 500 kg *Primnoa resedaeformis* and 25 kg of*Paragorgia arboreafromone* set conducted within the recently established Voluntary Coral ProtectionZone. Basedon the quantity of coral by-catch, the area appears to be relatively unfished. The crew was driven southwards due to pack ice and was unaware of the newly designatedvoluntary closure (H. Mercer, SeaWatch Ltd., personal communication, March 12, 2006). Once damaged, slow growth rates in species like P. *resedaeformis* (-0.17 mm yr'; Mortensen & Buhl-Mortensen, 2005), ***K.*** *ornata* (-0.06 mm yr'), and antipatharians (-0.07 mm y(^{1}) (Sherwood & Edinger, 2009) su9gest that recovery may take centuriestorecover (Andrewsetal., 2002; Sherwood & Edinger, 2009)

Keratoisis ornata thickets, documented by ROPOS video in HaddockandHalibut Channels (NAFO division 3Ps) were not documented within the newly established CAD-NAFO Corals Protection Zone (NAFOdivision 30), thereforeare notprotectedeven though they are among the longest lived species of coral found in the region (Sherwood &Edinger,2009)

Results of this IGPfunded project have significantly expanded our knowledge of coral distributions in the Newfoundland and Labrador region and have identifiedkeyareasfor coral protection. The 2007 ROPOScruisedemonstrated alternativenon-intrusive sampling methods not previously used in this region although used off Nova Scotia (Mortensenetal.,2000; Mortensenetal., 2006). Resultsdeiiveredprovideabroad overview of coral distributions with 36 species documented and m**apped.Notallareas** have been surveyed sufficiently (Hatton Basin) and other data sourcescouldbe consideredinordertohelpfilidata-poorareasfurthernorth(Le. NAFOdivisionsOB-2G) Currently, the dataset consists primarily of deep-sea corals with sponges now being identified; however, other significant structure forming megafa**una(Le. hydrozoansand** bryozoans) should be considered and incorporated in future sampling collection protocols used by DFOmultispecies surveys and fisheries observers

I gratefully acknowledge the fisheries observers, DFOtechnicians, and Canadian Coast Guard personnel whom were essential to this project. Special thankstoJ.Firth, P Veitch,D. Orr(DFONewfoundlandandLabradorRegion), T. SiferdandM. Treble(DFO Central and Arctic Region), andthe Northern Shrimp Research Foundation for invaluable datacontributions.ThisprojectwassupportedbytheDFOInternational Goverance Program. Last but not least, a special thanks to family and friends for their moral support and patience throughout the course of the project

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4 CONSERVATION OF DEEP-SEA CORALS IN THE NEWFOUNDLAND AND LABRADOR REGION, NORTHWEST ATLANTIC OCEAN

In the Northwest Allantic, distributions of deep-sea corals are now well mapped and conservation has improved with three interim protection zones now established off Newfoundland, Labrador, andeasternArclic, Canada: Narwhal-CoralProlectionZone, Voluntary Coral Protection Zone, and Canadian-NorthweslAllanlic Fisheries Organization(NAFO)CoralProlectionZone. Inadditionfiveseamounlsand 11 areas in international walers are ciosed temporarily by NAFO, to help proteclVulnerableMarine Ecosystems (VME) from Serious Adverse Impacls caused by bottom fishing. Corals are now recognized as one key componentofVMEs and in order to identify candidates and prolectknown concentrations within the Newfoundland and Labradorregionfivepriorily areas are recommended forfulure research; Hatton Basin, LabradorShelf, OrphanSpur - Tobin's Point, Flemish Pass, and southwest Grand Banks. Many ofthesareasare under threat from encroaching fishing pressures and are in need of urgent legislative protection, particularly Hatton Basin in the Labrador Sea where abundantlong-lived corals continue to be caught as by-catch by commercial fishing pralices

The United Nations GeneralAssembly(UNGA)Resolution61/105has called upon member states and Regional Fisheries Management Organizations (RFMO) to adopt measures to identify and protect Vulnerable Marine Ecosystems (VME) from Serious Adverse Impacts (SAI) caused by fishing activities(UNGA, 2005, 2006,2007; FAO, 2008). Deep-seacorals(Cnidaria), andsponges(Porifera),are now considered to be key components ofVMEs because of their vulnerability, fragilityandtheircontribution towards habitat complexity (OSPAR, 2004; UNGA, 2005, 2006; 2007; FAO, 2008; Rogersetal., 2008;ICES, 2008). Coralsarevulnerablebecausethey are long-lived (Roarketal., 2006) sessile animals with arboreal structures, 0ftenextendinghighoffthe seabed (Mortensen & Buhl-Mortensen, 2005). Their structures makethem susceptible to damage caused by anthropogenic activities, primarily bottom fishing (Watling & Norse, 1998; Krieger, 2001 ; Hall-Spenseretal., 2002; Stone, 2006). Oncedamaged,mostwill require decades or centuries to recQvertotheiroriginal state due to extremely slow growthrates(Risketal., 2002; Mortensen & Buhl-Mortensen, 2005; Roarketal., 2005; Traceyetal., 2007; Sherwood&Edinger, 2009)

Originally, only 'hard' coralswith a calcum carbonateand/orproteinaceious skeleton (i.e gorgonians, antipatharians, and reef-forming scleractinian**s)wereconsideredpartof VMEs,butnowseapenfieldsandspongemeadowsarealsorecognizedbecauseofthe** specific habitats they create when found in largeconcentrations(ESSIM, 2006; ICES, 2008). As part of the efforts to identify and protect concentrations of corals, the focus of this chapter will be to identify irnportant areas for coral conservation within the **Newfoundland,Labrador,andArcticregions, includingareaslocatedininternational** waters. In addition, the objectives will highlight coral conservationprogresstodate, and discuss challenges the Newfoundland and Labrador Region faces. Thischapler **concludes with recommendations on how to meet these challenges in order to** successfullyproteclcoralsintheNewfoundland, Labrador, andArclicregions

4.2,1 Scope of Research

The geographic scope represenls the northwest Allantic extendingnorthfromthe southern Grand Banks (Fig. 4.1) and encompasses North Atlantic FisheriesOrganizalion (NAFO) divisions; 3KLMNOP (Northeast Newfoundland Shelf, Grand Banks, Flemish Pass, and Flemish Cap), 2GHJ (LabradorShelf),and OAB (Hudson Strait, Southeast BaffinShelf,andBaffinBay).Informationusedinthischapteristakenfromprevious chaplers, as well as new findings and experiences gained throughoulthe course oflhe Newfoundland and Labrador Deep-Sea Coral Project; a programmesponsoredbylhe Department of Fisheries and Oceans Canada (DFO) in partnership with Memorial University (MUN)

Thestruclureofthischapterwillbeginwilh background informationdescribingwhy corals are irnportant, followed by conservation progress on the east coast of Canada including international waters located within Northwest Atlanti**cFisheriesOrganization** RegulaloryArea(NRA). Nexlwillfollowa brief overview of strategies used loprotecl corals as well as emerging legislative tools that eQuid be utilize**d. Priorityareasforcoral** proteclionwill be identified followed by challenges Newfoundland, Labrador, andCentral and Arctic Regions face in terms of marine conservation. The chap**terwillconcludewith** recommendations on how to help protect corals and their habitats within the **Newfoundland,Labrador, andArcticregions, anessential stepf**or Canada to achieve its global obligalions selforth underlhe UNGA Resolulion 61/105 (UNGA, 2006)

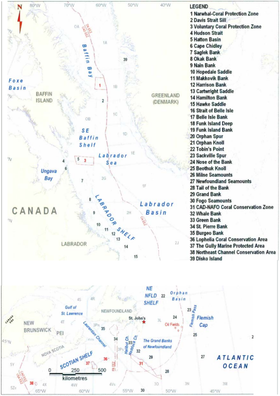

Figure 4.1. Map of study area highlighting important bathymetric features offthecoastof

4.3.1 **WhyAreCorals Important?**

Ascoastalresourcesaredepleted(Jacksonetal., 2001). fishingeffortsnowtargetthe deep-sea and are expanding north into arctic waters targeting Greenland halibut and northernshrimp(Murawskietal., 1gg7; Casey&Myers, 1g98; Koslowetal., 2000;

thesis the "deep-sea", or bathyal zone, extends from the continental shelfbreak to 2000 m, butnotincludingtheabyssalplains. These deep-sea areas have low rates of natural **disturbance,andarefragileduetothesensitivebenthiccommun**itles that exist there These communities are comprised of K-strategistspecies that**exhibitconservativelife-**history traits such as: long life spans, slow growth rates, low fee**undity, latematuration** periods, and discontinuous recruitment periods (Merrett & Haedrich, 1997; Koslowetal., 2000; Roberts, 2002)

Deep-sea habitats are composed of relatively stable physical (e.g. bathymetric features) and biological (e.g. megafauna) features. Megafauna such as corals are known as 'sea-trees' becauseoftheirarborealshapes, andnotonlyinhabitthebenthosbutare fundamental components of it as well. Thecorallum, the entire cor**alcolony, providesa** three-dimensional structure constructed of either calcium carbonate (aragonitic or calcitic) and/orproteinaceiaus gorgonin, a complex protein. Groups of coral colonies provide vertical relief on the sea floor, and create microhabitats within and in-between colonies(Tissotetal., 2006). A terrestrial analogy is like birds utilization of trees, with the complexity of tree branches providing important nesting and fora**geareas. Inthecaseof** corals, coloniesactasrefugiaforjuvenilefish(Etnoyer&Warrenchuk,2007;Mooreet al.,2008)andotherinvertebrates(Buhl-Mortensen&Mortensen, 2005). It has been shown that large bamboo eorals *(Keratoisis ornata* Verrill 1878) can dissipatebenthie boundary layer energy from loeal eurrent regimes, potentiallyprovidingrestareasfor demersal fish (Zedal & Fowler, 2009). Evenafteraeoraleolonyhas perished, the skeletoncanpersistforanextendedperiod(Edinger&Sherwood, 2009), eontinuingto provide habitatstrueture in deep-sea eeosystems (Opresko, 2005; Yoklavieh& Love, 2005; Loveetal., 2007). Nonetheless, these deep-sea struetures are fragile and are easilydisturbedandbroken. Itiswelldoeumentedthatglobaldeep-seabotlomfisheries, partieularly bottom trawling, are damaging and destruetive to corals, and is the leading threattotheirexistenee(Probertetal., 1997; Watling&Norse, 1998; Fossaetal., 2001; Hall-Spenseretal., 2002; Grehanetal., 2005; Mortensenetal., 2005, Wheeleretal., 2005; Stone, 2006; Reedetal., 2007). Originally, mobilebotlomfishinggear(e.g dragging or trawling) was eonsidered to be the primary cause (Krieger, 2001; Hall-Speneer etal., 2002; Stone, 2006; Clark & Koslow, 2007). However, other studies have shown that fixed gear types (i.e. longlines, gillnets, and erabpots)ean also damage eorals but toa lesser spatial extent(Mortensen etal.,2005; Wareham & Edinger, 2007, Edinger et al.,2007a, b)

4.4.1 **Maritimes Region**

Deep-sea corals are considered an excellent 'flagship' species for marine conservation More importantly, they can aet as 'umbrella speeies', meaning that oneeprotected, other marine speeies that live on, between, or amongst them will also be proteeted (see Lambreek, 1997). Researeheruisesandopportunistiedataeolleetions on corals played a key role in the establishment of *The GullyMarineProteetedArea (F*ig. 4.2)onthe SeotianShelf. TheGullywasAtlantieCanada'sfirstMarine Proteeted Area (MPA) under the OceansAc/(DFO, 2004a). Itisa large underwater canyon encompassing-2,364 km' andissubdividedintothreezoneswithvaryingdegreesofprotection. Zone1 represents the deepest section and is fully protected; no human activities are permitted with the exception of authorized scientific research. Zone2represents the canyon head, feeder canyons, and continental slope. Zone 3 represents the adjacentsandbanks Zones2and 3 have strict protection with limited fishing permitted: longlinegearis permitted butnottrawlgear.Asa result of this closure, endangered species that also inhabit The Gully **MPA** (e.g. Northern Bottlenose whale, *Hyperoodon ampulla/us)* are also protected (COSEWIC, 2002). The main objectives for The GullyMPAareto conserve and protect the natural biological diversity, andensureits long-term health, notablytheuniquedeep-seacoralsandendangeredbottlenosewhalesthatareknown to inhabit the canyon (DFO, 2004a)

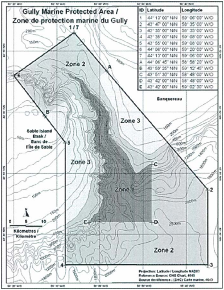

Figure 4.2. Map of *The GullyMarineProtectedArea(DFO, 2004a).* Mapcourtesyof

Other areas on the Scotian Shelf protected under the *FisheriesAct* include the *Northeast ChannelCoralConservationArea(2002)*, *and Lophetia[Stone* Fence*JCoral Conservation Area* (2004). These areas were protected in order to preventfurther damage to large gorgonians and framework-forming scleractinians from bottom fishing activities(DFO, 2002;DFO,2004b)

The *NortheasIChannelCoralConservationArea(Fig*. 4.3) is-424km' in area. It is located between Georges Bank (United States) and Browns Bank(Canada) on the southern tip of the Scotian Shelf. Initially, itwasidentifiedbyfishersasanimportantarea for corals based on unusually high by-catch rates(Breezeetal., 1997). Nowprotected, it

the overall area and is fully-protected with no human activities permitted. The second, ***LimitedBotlomFisheriesZone,representstheremaining10% andi***s restricted to longline fisheries targeting groundfish with all vessels requiredtohaveafisheries **observer onboard.** The main objectives of this conservation area are to conserve and protect the biological diversity of large deep-sea gorgonian corals found within its boundaries (DFO, 2002)

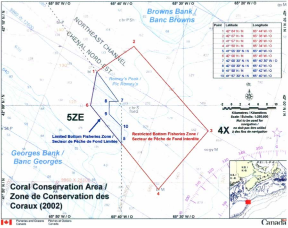

Figure 4.3. Map of the *Northeasl Channel Coral ConservalionArea* (DFO, 2002). Map courtesy of DFO Canada

The *LopheliaCoralConservationArea(Fig*. 4.4) is 15km' inareaandislocatedonthe most northeasterly corner of the Scotian Shelf. Known as the Stone Fence, it was first identified asa unique area for corals by Captain Collins (Collins, 1884).Currently, no fishing activities are permitted within the area. The objectives of this conservation area are to prevent further impacts to the already badly-damaged *Lophelia pertusa* (Linnaeus, 1758)coralreefcomplexandtoallowforitsrecovery(DFO, 2004b). Itis noted that at thetimeofitsdesignationasa conservation area, Stone Fencewa**stheonlyknown** occurrence of *Lophelia pertusa* in Canadian waters. Since then, live colonies have been documented in The Gully MPA during the 2007 ROPOS (Remotely Operated Platform for Ocean Science) expedition (Gilkinson& Edinger, 200g)anddeadfragmenlshave been documented on the Flemish Cap during the 2009 Northwest Atlantic Fisheries Organization Potential Vulnerable Marine Ecosystems Impacts 0fDeep-seaFisheries (NEREIDA)expedition(K. Macisaac, Bedford Institute of Oceanography, personal communication, July5,2009)

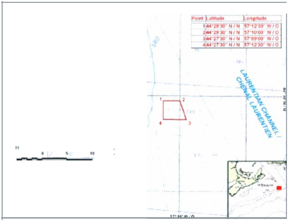

Figure 4.4. Map of *Lophelia Coral Conservation Area* (DFO, 2004b). Map courtesy of

4.4.2 Newfoundland and Labrador Region

There are no deep-sea coral MPAsestablished in Newfoundland, Labrador,orArctic regions. Several areas have been identified as coral diversity hotspots (Gilkinson& Edinger, 2009), and, asa result, three have been granted interim protection. The first two were closed under the *Fisheries Act* by DFO Canada (CAD): the *CAD-NAFO Coral ProteclionZone* and the *Narwhal-CoralProteclionZone*. Thethird, the *Voluntary Coral*

ProlectionZone, is a voluntary closure initiated by three fishing industry organizations; Groundfish Enterprise Allocation Council(GEAC), CanadianAssociationofPrawn Producers (CAPP), and the Northern Coalition (NC)

The *CAD-NAFO Coral Protection Zone* (Fig. 4.5), a mandatory interim closure that will be revistited in 2012, islocatedonthesouthwestslopeofGrand Bankandstraddles nationalandinternationalwaters. Itis-14,040km' insizeandfaliswithinNAFOdivision 30(NAFO, 2007). ItwasinitiatedbyCanadianfisheriesmanagersbased loosely on known *coral* distributions, and implemented by NAFO contracting parties (Gilkinson & Edinger, 2009). The purpose of the closure is to protect corals foundwithinits boundaries but more importantly 'freeze the footprint' of fishing activities, and exclude fishing indeepwatersbetween800-2000m (NAFO, 2007). Asillustratedin Figure4.5, many of the most diverse sets are found in waters shallower than the coral protection boundaries. Furthermore the coral protection zone does notinclude the abundant *K.*

Channels(NAFOdivision3Ps;seeChapter3, Fi9· 3.8)

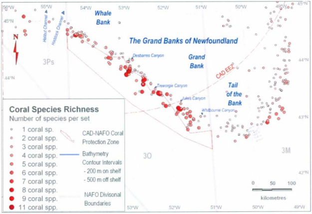

Figure 4.5. Map of *CAD-NAFO Coral Proleclion Zone* (NAFO, 2007) with coral species richness. Richness was determined by the number of coral species documented per set from DFO Multispecies Surveys and fisheries observers from 2002 to 2007

4.4.3 Central and Arctic Region

The *Narwhal-Coral Prolection Zone* (Fig. 4.6) is relatively small compared 10 the olher areasdescribed, al-8,000 km' in size. II is localed northoflhe Davis Slrait Sill in

help prolect Narwhals from enlanglemenl in gillnels while in lheirover-wintering grounds, and also protect their primary food source, Greenland halibul(*Reinhardlius hippoglossoidesWalbaum*, 1792; DFO. 2007a). Gear loss is inevilableinlhisareadue to strong currents and the annual flucluation of ice moving throughthe**narrowpassage** of Davis Slrail (Jordan & Neu. 1982). From2004-2006-600gillnelsconstrucledof durable microfilament material were lost in NAFO division 0A, the equivalent of 54 km of net(DFO, 2007a)

TheclosureappliesonlytothedeepwaterGreenlandhalibutfishery, andexcludes the shrimp fishery which target shallower depths «500 m). Vessels are restricted to four fishingdays/peryearwithintheprotectionzoneregardlessofgear types used (i.e trawls, gillnet or longline). In 2006, corals were added to the overallconservation **objectives. How8ver, progresstostrengthenconservationandprotectionmeasureshas** been slowtomaterializeduetoa lack of political will (e.g. support, monitoring, and funding) and disputed byindustry. Asa result, the area is somewhat inconsistently managed asa protection zone and violations are reported yearly(M. Treble, DFO Central and Arctic Region, personal communication, May6, 2009)

During a DFOfall survey in October 1999, a large catch of corals was documented within the same area as the existing closure (see Fig. 4.6). Thecatchwasestimatedat 2-3 tons and tore most of the trawl net clear from the footgear. When retrieved, only shredded pieces of net entertwined with broken coral fragments remained(D. Pittman, DFO Newfoundland and Labrador Region, personal communication, July 2, 2009) Samples with live tissue were later identified as *Keratoisis* sp. by Dr. Ole Tendal from the ZoologicalMuseum, UniversityofCopenhagen(M. Trebel, DFOCentralandArctic Region, personal communication, May 20, 2008): as well, I inspected a small sketetal fragment from this set and concur with initial identification

Figure 4.6. Map of *Narwhal-CoralProlection Zone* (DFO, 2007a) with coral species richness. Richness was determined by the number of coral species documented per set from DFOMultispecies Surveys and fisheries observers from 2002 to 2007. Note the largecatchofKeratoisissp. documenledinOclober1999wilhinthe existing closure

The *Voluntary Coral Prolection Zone* (Fig. 4.7.) encompasses an area-12,500km', located immediately adjacent to Hudson Strait in an area known as Hatton Basin; it falls on lhe boundary between NAFO divisions 2G and OB (MPA News, 2007). Il was iniliated and implemenled by three fishing industryorganizalions: Groundfish Enlerprise AliocationCouncil(GEAC), CanadianAssocialionofPrawnProducers(CAPP), andlhe Northern Coalition (NC). The purpose of the closure is to avoid fishing-related damage to five species of corals, which include; *Primnoa resedaeformis* Gunnerus 1763, of conduct has been developed by industry for its membersoperalin9 in the area. The code requires operators to halt fishing activities when significant concentrations of any of the five coral species are encountered. However 'significant' is notdefined, and is appliedsubjectivelybasedontheoperator'sjudgement.Itistheoperator'sresponsibility to report each significant encounter and move elsewhere to resumefishing. Aswell, the code only applies to members of the three organizations stated above, and exempts the participation of Aboriginal groups and small boat operators. The closure and code of conduct employ the *honour system;* therefore, there are no legal ramifications or **enforcement measures against non-compliant resource users. Most members abide by** the closure but some fishing still occurreswithin the boundaries of the voluntary closure (Warehametal., 2010).Regardlessofitsflaws, theclosureisa "good first step" towards protecting corals and sponges (MPA News, 2007). However, to fullyprotectcoralsfound in this area, the existing closure must be extended based on newinformationthat was not previously available (Warehametal.,2010)

These findings document species richness (Fig. 4.7.) and; more importantly, document large catches (> 500 kgs) of corals particularly *Paragorgia arboreaandPrimnoa resedaeformis*(Fig. 4.8.), twolargelong-livedspeciesnotfound frequentiy anywhere elsewithintheNewfoundland, LabradorandBaffin Islandregions(Wareham & Edinger, 2007; Wareham, 2009). The Voluntary Closure in an interim measure that will be revisited in 2012 by the fishing industry and could be revoked ifmembersdonot

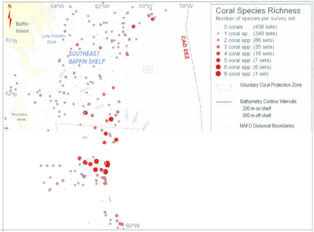

Figure 4.7. Map illustrating the Voluntary Coral Protection Zonewithcoralspecies richness. Richnesswasdeterminedbythenumberofcoralspeciesobservedperset from DFO Multispecies Surveys and fisheries observers from 2002 to 2007

Figure. 4.8. Map illustrating coral and sponge by-catches using thresholds recommended by the NAFO WGEBM for international waters and applied to Research Survey data (2005-2008) within national waters. Thresholds for largegorgonianby-catch are> 2 kgs and sponge by-catch thresholds are > 75kgs. Note: actualsetweightsfor coralsareillustrated, however, actual sponge weights are not, instead each point representsanoccurranceofspongeby-catch>75kgs

NAFORegulatoryAreasontheHighSeas

Efforts to protectVMEs, namely corals and sponges, are also being madein international waters within the **NRA** with five seamounts closed to bottom fishing (NAFO, 2006; 2008d). Seamountclosureswereannouncedshortlyafter UNGA Resolution 611105 (2006), butwillbereviewedin2010. Theprovisionalfishing ban includes the NewEngland, Corner, Fogo, and Newfoundland Seamounts, andOrphanKnoll (Fig 4.9). These closures are interim measures that also permit small-scale exploratory

area" is currently undefined. Seamounts are unique ecosystems because they provide genetic connectivity in the deep-sea, host endemic species, an**dprovideareasofrefugia** (Parinetal., 1997; Richerde Forgesetal., 2000;Smithetal., 2004; Stocks& Hart, 2007; Robertsetal., 2009). Similartootherdeep-seaenvironments,seamountsare **extremelyvulnerabletoanthropogenicdisturbanceswithlasti**ngeffects, as evidenced on the Corner Seamounts by trawl door scars left from fishing activitiesconductedinthe 1960s(Walleretal., 2007)

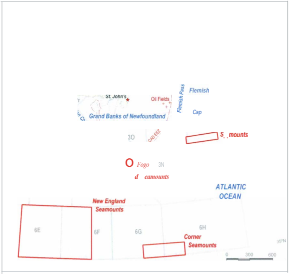

Figure 4.9. Map of seamounts closed to bottom fishing within the NAFO Regulatory Area

In Canada, several key legislative tools are used to manage and protectCanada's marine resources (see Campbell & Simms, 2009), most notably the *Oceans Act (1997)* whichinciudesCanada'sOceansStralegy(2002j, Canada'sOceans*AclionPtanl*

(2005), *MarineProlecledAreasSlralegy(2005)*, *HealthoflheOceans Iniliative* (2007), and *Fisheries Acl(1985}*

Canada'sOceansAclisanimportantmanagementtooldesignedtohelpconserve, protect, and develop marine resources. The *Acl* is based on threeguidingprinciples sustainable development, the precaulionaryapproach, and integrated management. The *Acl* promotes sustainable development using a precautionary approach-whichpurports that government should err on the side of caulion when lack of scienlificdalaexists. 1l also promotes an integrated management approach to help bring together all interested parties (e.g. governments and stakeholders) in order 10 work towards common goals Ultimately, the Acl assigns the Minister of Fisheries and OceansCanadalhe responsibility for leading and facilitating the managementofC**anada'soceanresources**

Canada'sOceansSlralegyiscontainedwilhinlheOceansAclandoutlines the policy statement for a national direction- Ufa ensure healthy, safe, a**ndprosperousoceansfor** the benefil of present and fuluregenerations of Canadians". The stralegyapplies to esluaries, coastal waters, and deep-sea ecosystems within nat**ionalboundaries**

Canada's *Oceans Aclion Plan* communicates a national approachforsustainable

and security; 2.) Inlegraled oceans managemenlforsustainabledevelopment; 3.) Health of the oceans; and 4.}Ocean science and technology. Large Ocean Management Areas (LOMAs) fall under the *Oceans Action Plan*, and are management areas identified within the oceans bordering Canada. Currently there are five LOMAs designated, including;

undertaken for each LOMAsuch as the identification of Ecologically andBiologically

Significant Areas (EBSAs). These are unique areas that are considered relatively more important than surrounding areas based on three primary criteria (**uniqueness,** aggregation and fitness consequences) and two secondary ones (resilienceand naturalness). Currently DFO Newfoundland and Labrador Region is moving forward on developing key marine ecosystem componentsand/or properties for the Placentia Bay/Grand Bank LOMA to help with risk analysis, assessments, and recommendations for conservation. Both LOMAand EBSAassessmentswili be used to develope future

Canada's *Marine Protected Areas Strategy* provides federal departmentsandagencies (DFO,EnvironmentCanada, andParksCanadaAgency)withguidelinestohelpdevelop a cohesive and complementary network of MPAs (DFO, 2005a). These new MPAs will be established under the *Oceans Act* using an integrated oceans m**anagement** framework, and will promote healthy oceans and marine environments (DFO, 2005b) **Marine Protected Areas provide legal protection to commercial and non-commercial** species and their habitats, endangered and threatened marines**peciesandtheir** habitats, uniquehabitats, anduniqueareasofhighbiodiversity(i.e. EBSAs)

The *Health* of *the Oceans Initiatives* (HOTO) is the latest government programme that will take the necessary steps to protect fragile marine environme**ntsthroughthecreation** of nine new MPAs (DFO, 2005b). It also includes a commitment for Newfoundland and Labrador Region to develop a coral conservation strategy by2012 (Campbell & Simms, 2009), and continue collaborations with World Wildlife Fund (WWF) Canada and other ocean interests. It will strengthen prevention measures for pollution, invest in scientific research to support and advice on MPAnetworks, and expandonanddevelopfuture collaborations-oramongst domestic and international institutions(e.g. NEREIDA2009-2010 Expeditions)

Canada's *Fisheries Act* (amended 1985) is the most powerful management tool for **marine conservation. It was implemented to help prevent harmful alteration, disruption or** destruction (HADD) offish habitats, and to help prevent the deposition of substances deleterious to fish *(Fisheries Act* s.34-36). Based on the *FisheriesAct*, the definition of "fish" includes "rnarine anirnals and any parts of marine animals", **andthereforecanbe** interpreteto include corals. The *Act* defines fish habitat as;

> "fish habitat[s]" spawning grounds and nursery, rearing, food supply and **migration areas on which fish depend directly** or indirectly in order to **carry**

It has been shown that corals provide habitat for fish (Auster, 2005; Costelloetal., 2005; Robertsetal., 2006)andactasnurseries(Etnoyer&Warrenchuk, 2007); therefore,

apply to fishing because "fishing cannot be considered a work or undertaking" (s. 35[1) *Fisheries Act).* The *Fisheries Act* does provide reSQurce managers with the legal power to reduce, lirnit, and restrict fishing activities in any mannerdeamed necessary to protect

Protection Zone, and *LopheliaCoralConservationAreaareallexamp***lesofmarine** areas established and protected under the *Act*. TheActallowsciosurestobe established instantaneously but protection is not permanent and can be reversed as

Canada's national efforts toward marine conservation are also being driven by international agreements such as the United Nations (UN) *Oceans and Law of the* Sea *Convention(1982),theConventiononBiofogicafDiversity(C*onvention, 1992), UNFish

StocksAgreement(1995), andthe Food and Agricultural Organiz*ationCodeofConducl for Responsible Fishing* (2005)

The UN *Fish Stocks Agreement* puts forth several important guiding principles and approaches such as Article 5 (sustainable fisheries ecosystem approach), Article6 (precaulionaryapproach),andArticle7(compatibilityprinciple). However, more recently the *UNGA Resolution* 61/105 (2006) has been the most influential catalyst for recent conservation efforts in Canada as well as within NRA (NAFO 2006; 2007; 2008a, b;

The *UNGA Resolution* 61/105 (paragraph 83a-d) applies regulations pertaining to high seas bottom fisheries. HighseasaredefinedundertheConvention on the High Seas (2005)asoceans, seas, andwatersoutsideofnationaljurisdictions. This means that nations conducting bottom fishing on the high seas can now be held accountable for theiractionsorlackthereof, and must manage these areas inorderto prevent significant adverse impacts to VMEs. Nations actively fishing the northwest Atlantic include European Union (EU) countries (Spain, Portugal,Estonia, Latvia,Lithuania, Poland), the Russian Federation, Iceland, Norway, Denmark (Faroe Islands and Greenland), Republic of Korea, Ukraine, Cuba, United States, Japan, France (SaintPierreet Miquelon), and Canada (NAFO, 2009c)

Section 83a ofUNGA Resolution 61/105 calls for impact assessmentsofhighseas **fisheries to determine how these impact VMEs and how to prevent significant adverse** impacts to VMEs. This section has not been addressed but will likely be the next foeus of

Section 83b of the resolution calls for the long-term sustainabilityofdeep-seafish stocks. This can be achieved using fishery quotas, gear restrictions and effort limitations

UnderNAFO, mostdirectedspecies(Greenlandhalibut,redfish, northernprawn, and skate),with the exception of grenadiers, are regulated through the allocation of quotas Areas already under protection (CAD-NAFO Coral Protection Zone) have gear restrictionsandlimitedeffortthroughclosures. Suchactionswill contribute to long-term sustainabilitybut may not be enough with most deep-sea fish species considered over-exploited (Merrett & Haedrich, 1997; Haedrichetal., 2001; Devineetal., 2006)

to occur, such as, concentrations of corals and sponges, and seamounts. In 2006 several seamounts were closed to bottom fishing (see Fig. 4.9; NAFO, 2006), with Fogo Seamountsaddedtothelistin2008(NAFO, 2008d). Twentypercentofeachseamount can besubjectedtoexploratoryfishing(NAFO, 2006)whichwili be determined in later years based on whether substrates are suitable to conductfishing (e.g. trawlable)

In 2008, the Working Group on Ecosystem Approach to Fisheries Management (WGEAFM) was formed as a subsidiary to NAFO Scientific Council (SC) to help address

information, seven candidateVMEswere identified (Fig. 4.10; in green) and put forth to NAFO from the WGEAFM (NAFO 2008c). From the original candidates, number seven, southern Grand Bank, was previously closed in 2007. The WGEAFM has recommended

present 800 m boundaryintoshallawerwaters, in order for this c10sureto be more effectiveinprotectingcorals(NAFO, 2008c;seeFig.4.5)

As of January 1, 2010, based on the recommended VME candidates, 11 areas were closed(Fig. 4.10; inred)onaninterimbasis(Jan.1, 2010-Dec. 31, 2011)toallbottom fishing(NAFO, 2010)

Figure 4.10. Location of candidate VMEs (in green) identified and recommended to NAFO by the Working Group On Ecosystem Approach To Fisheries Management (NAFO, 2008e), and actual areas designated as interim coral protection zones (in red) byNAFO, based on candidate VMEs (NAFO, 2010)

Section 83d of the resolution requests encounter protocols be developed and implemented on the high seas. Such protocols would require fishing vessels to "cease fishing" in areas where VMEs are encountered, NAFO developed an encounter protocol for its contracting parties in 2008, which classifies the NRAas either historically fished areas or new fishing areas defined as virgin grounds or depths > 2000m. For all areas, historic or new, the encounter protocol states that if by-catch of corals ≥ 60 kg and/or sponge ≥ 800 kg per fishing set are encountered then the cease rule applies and fishing captains must report the VME to NAFO Scientific Council. If the encounter occurs within [redacted]

[redacted]

On a national level, Canada has developed the *Fisheries Renewal Program,which* includes several policies that will guide fisheries management and help protect VMEs as well as align national policies with current international agreements(e.g. UNAgreement on Straddling and Highly Migratory Fish Stocks). The *Fisheries RenewalProgram* includes; the *Sustainable Fisheries Framework* (DFO, 2009b), *Managing the Impacts on SensitiveBenthicAreasPolicy(DFO, 2009a), andtheEcologicalRisk Analysis* (DFO, 2009a). These policies and strategies Qutlinea national direction towards sustainable development, and integrated management, while exercising the precautionary and

The *Sustainable Fisheries Framework* (SFF) *was* developed to promote environmentally sustainable fisheries while supporting economic prosperity. It is comprised of four elements: conservation and sustainable use policies; economic policies; governance policies and principles; and planning and monitoring tools (DFO, 2009b). Under conservation and sustainable use policies, three new policies have been introduced; Managing Impacts of Fishing on Sensitive Benthic Areas (Habitat, Community, and Species), AFisheryDecision-Making Framework IncorporatingthePrecautionary Approach, and New Fisheries for Forage Species

Managing the Impacts on Sensitive *Benthic Areas Policy* is a highlyanticipated legislative tool developed by DFO. The purpose is to;

> "Help DFO manage fisheries to mitigate impacts of fishing in sensitive benthic areas or avoid impacts of fishing that are likely to cause serious or
>
> **applies to all commercial, recreational, and Aboriginal marine fishing**

economiczone" (DFO, 2009a)

Thepolicywillsupportdatacollectionandidentificationofsensitiveareas. Potential impacts on sensitive areas (e.g. habitat, communities, and species) from fishing activities will be determined through the *Ecological Risk Analysis Framework* developed by DFO Fisheries and Aquaculture Managment(FAM). Deep-sea corals and sponge concentrationswillbethefirstareasidentified(DFO,2009a). Management decisions made under this Policy are guided by the Precautionary Approach andEcosystem Approach. Its intention is to 8xercise a higher level of risk aversion for: frontier areas (e.g.newfishingareas), historicallyfishedareasthathavenotbeenfished in a number of years, and areas where specific gear types have not been previouslyused

The *Policy for Managing the Impacts* of *Fishing on Sensitive Benthic*Areascouldbea large step forward for Canada, directing how the nation manages a**ndprotectsitsocean reSQurces.HOW8ver, thedefinitionofFrontierAreasneedstobe** revised. Currently, the

"without a history of fishing in Canadian waters. This is interpreted to mean

of fishing **and little if any information is available concerning the benthic** features (habitat, communities and species) and the impacts of fishing on thesefeatures" (DFO, 2009a)

The policy identifies two types of frontiers areas: waters deeperthan 2000 m, andthe high Arctic. Unfortunately, the definition excludes patches of 'virgin' areas within historically-fished grounds (e.g. parts of Hatton Basin) where sensitivebenthicspecies (e.g. corals, sponges) are suspected but little or no information is available (Wareham &

Edinger, 2007; Gilkinson&Edinger, 2009; Wareham etal., 2010). These potential 'patches' could be much larger in area than those areas actuallyfished. Asa result, the

'patches' of virgin grounds that are considered 'frontiers' by the scientific community but are not defined under the current policy

Under the *Health oflhe Oceanslnilialive* (2007), the Canadian FederalGovernment plans to protect fragile, ecologically-significant marine areas by establishing nine new MPAs. The process of MPA selection is time-consuming. It starts with a list of candidate

several Areas Of Interest (AOI) and then subjected to public consultation. Itistheintent thatoneofthesiteschosenasanAOlwilibeformallydesignatedaMPAby2012(N Templeman, DFO, personal communication, Ocl. 20, 2009). However, the entire process can take years to complete and does not always end with success (e.g. LeadingTickles, NL).WithinthePlacentiaBay/GrandBanksLOMA, 11 EBSAshave been identified, with the *SouthweslShelfEdgeandSloperanked* high for unique coral concentrationsand biodiversity(DFO, 2007b). Inthespringof2009, DFOcompletedinternal and external consultations on five priority EBSAs (Southeast Shoal and tail of the Banks, the Southwest Shelf Edge and Slope, Laurentian Channel and Slope, Sl. Pierre Bank,and NortheastShelfandSlope), asakeystepintheprocessofidentifying a potentialAOI in the Newfoundland and Labrador region (N. Templeman, DFO, personal communication, Ocl.20, 2009)

documented and information on the Arctic region is increasing. When data on corals are compiled into distribution maps; patterns of coral frequencies emerge. Basedonthese maps, five areas are highlighted as potential candidates for marine protection and future scientific research. The areas of interest are described belowfrom north to south (Fig 411)

and Labrador (Haedrich & Gagnon, 1991) but are not described here because they are not sampled by DFO multispecies surveys or by fisheries from which samples were collectedforlhisthesis.Examplesofsuchinshoreareasofimportance indude Bayd'

observed on submersible dives (Haedrich & Gagnon, 1991). These andotherinshore areas merit further study

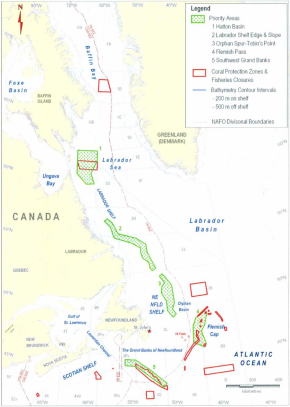

Figure4.11 . Priorityareasforfuturedeep-seacoralresearchare highlighted in green,

4.6.1 Hatton Basin (Nalional Walers)

The Hatton Basin is located between southeast Baffin Island and the northern tip of Labrador. The area is influenced by cold waters originating from the higharcticviathe Hudson Strait and Labrador Current flowing from Baffin Bay (Drinkwater & Harding, 2001). The Hatton Basin and surrounding areas are important fishing areas for Greenland halibut and northern shrimp (Wareham et al., 2010), and are known for strong currents (Griffithsetal, 1981; Piper, 2005), roughsubstrates(D.Orr, DFONewfoundland and Labrador Region, personal communication, Sept. 2005; Warehametal., 2010)and high coral by-catch (Maclssac et al., 2001; Gass & Willison., 2005; Wareham, 2009; Wareham etal., 2010). Trawl by-catch rates of coral from the Hatton Basin are comparable to rates documented from 'virgin' waters off Alaska (Kreiger, 2001)andon Tasmanian Seamounts (Anderson & Clarke, 2003)

Scientific survey data and observationsfrom fisheries observers fram the area have documented high diversity (Fig. 4.12) and abundance (Fig. 4.8)0flarge gorgonians (e.g P. *resedaeformisand* P. *arborea)* not previou51yobserved in theNewfoundlandand Labrador region (Wareham & Edinger, 2007; Wareham, 2009; Wareham et al., 2010). As well some fisheries observers have noted a temporal change in the average size of corals, particularlyP, *resedaeformisandP. arborea, whichapp*ear to have declined compared to the original "Glory Hole Days" in the early 19905 when commercial fisheries first expanded into this region (R. Beazley, SeaWatch Ltd" perso**nalcommunication,** March 16, 2007)

for corals. Also known a5 Cape Chidley, it has been highlighted inearlierstudiesasa coral 'hotspot'(Maclsaacetal., 2001; Gass&Willison, 2005). Currently, theonly protection offered for Hatlon Basin and the surrounding areas is the industry-led Voluntary Coral Protection Zone and associated code-of-conduct. Based on commercial log book data, the centre of Hatlon Basinislargelyavoided, andmajorityoffishingeffort is concentrated on the outer edges and conlinental slope (Wareham etal., 2010), The voluntary closure protects a portion of Hatlon Basin, which hasreducedfishing within its boundaries, but has not haulted all fishing activities (Wareham etal., 2010)

Concentrations of large gorgonian corals still continue to beeaptured as by-catch in the vicinity as well as within the closure (see Figs, 4,7, 4.8, 4.12, &4.13) indicating that the presentvoluntaryclosureisinsufficientinsizeandlocation(Warehametal., 2010) Legislative measures are needed to adequately protectconcentrations of corals. As well, furtherinsiluresearch is needed to properly assess and delineate the full extent of coral concentrations within this unique area (Edingeretal., 2007a; Wareham & Edinger, 2007; Gilkinson & Edinger, 2009; Wareham, 2009; Wareham et al., 2010). Other voluntary closures off British Columbia, Canada have not sufficiently protectedspongesduetothe 'fear factor', where fishing intensifies prior to a closure and/*or* within the vicinity of the proposed closure (Ardron etal., 2007; Robertsetal., 2009)

Large catches of corals (see Fig. 4.8); and the long-lived species encountered (see Chapter 3, Fig. 3.3); combined with high species richness (see Fig. 4.12); indicate that portions of the Hatlon Basin area have never been impacted bybotlom fishingpratices **ThisWDuldsuggestthatremnantpocketsoffrontierorvirginse**a floor exist within and around the Hatlon Basin, and if so, are currently not protected underDFO's 'Frontier Areas Policy' based on the current definition of 'frontier' (seesection4.5.3; DFO, 2009a)

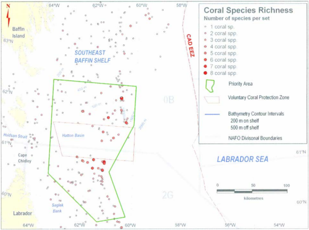

Figure. 4.12. Map of Hatton Basin, priority area for future deep-sea coral research. Map illustrates the current Voluntary Coral Protection Zone with coral species richness Richness was determined by the number of coral species observed per set from DFO Multispecies Surveys and fisheries observers from 2002 to 2007

Figure. 4.13. Coral by-catches from Hatton Basin: *(left)Paragorgiaarborea* by-catch on trawl deck from Northern Shrimp Research Survey, and (right) *Primnoa resedaeformis* fragments *entangled* in a commercial gill net. Photo courtesy of DFO

4,6,2 labrador Shelf Edge and Upper Slope (National Waters)

The I abrador Shelf extends parallel to the labrador coast and includes numerous banks incised with shelf-crossing troughs. The outer edge of the shelfis inftuenced by the cold I abradorCurrentftowing southward. The southeast portion, along the edge and slope

diversity of all the priority areas; surpassed only by the Southwest Grand Banks (Wareham & Edinger, 2007). It also had the highest occurrence of 10sttrawls(Hughes, 2009) indicating rougher substrates. Sensitive VME species include largegorgonians; ***Paramuriceaspp., Paragorgiaarborea, andPrimnoaresedaeformis.*** This area is recommended asa priority area (Fig. 4.14) for further research basedonthediversityof corals, and the presence of rare and sensitive species

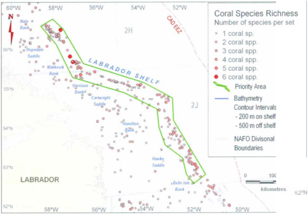

Figure 4.14. MapoftheLabradorShelf, priorityareaforfuturedeep-seacoralresearch Map illustrates coral species richness which was determined by the number of coral species observed per set from DFO Multispecies Surveys and fisheriesobserversfrom

4.6.3 Orphan Spur and Tobin's Point (National Waters)

and is located northeast of the island of Newfoundland. Historically,thisshelfwasan important fishing area. Today, fishing efforts are now more focused on the edge and slope in deeper waters targeting Greenland halibut using otter trawls, longlines and gillnets than pasldecades(Hughes, 2009). On the Northeast NewfoundlandShelftwo areas important for corals have been identified: Orphan Spur (Piper, 2005), previously areas are located on the outer edge of the continental shelf

These areas were first identified from observer data as coral diversityhotspotsand further supported by DFO survey data (Wareham & Edinger, 2007; Wareham, 2009) Gear loss by gear type documented by observers *(2006-200B)* indicates a greater loss of trawl gear around Tobin's Point (Hughes, 2009) compared to Orphan Spur. This would indicate rougher substrates in this area. HOW8ver, coral speciescomposition, such as

Ingeneral,coralfrequencies-of-occurrencearehighwithrelatively moderate diversity compared to other priority areas. Sensitiv8 species documente**dinthisareainclude** several rare, largegorgonians(Fig. 4.15; e.g. P. *arborea,* P. *resedaeformis*, and *Paramuriceaspp.), and* numerousantipatharians, all of which require hard substrates for

Figure 4.15. A large intaclParagorgiaarboreacolonycollectedjust north of Tobin's Point during Ihe2006 DFOfalisurvey. Samples of this species and size, arerelatively infrequent

To date, Tobin's Point and Orphan Spur areas (Fig. 4.16) have had the highest frequencyofantipalharianswilhintheNewfoundland, Labrador,andArcticregions (Tendal, 2004; Gass & Willison, 2005; Wareham & Edinger, 2007; Gilkinson & Edinger, 2009). Based on Ihis informalion, the edge and slope of the NortheastNewfoundland Shelf is identifiedasa priority area in need of *in situ* research a**ndurgentprotectiondue** to the intensity of fishing effort presently conducted in this area

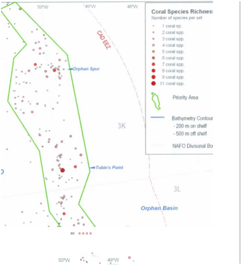

Figure 4.16. Map of Orphan Spur-Tobin's Point, priority area for future deep-sea coral **research. Map illustrates coral species richness which was determined by the number of** coral species observed per set from DFO Multispecies Surveys and fisheriesobservers

4.6.4 Flemish Pass (Internalional Walers)

Flemish Passisa deep underwater trough that separates the Canadian continenlal shelf from Flemish Cap and is heavily inftuenced by the cold LabradorCurrent.Multispecies surveys conducted by Canada and groundfish surveys conducted by Spain (EU) have documented frequent occurrences ofantipatharians in this area, **mostnotably**

Stauropathesarctica(Lutken, 1871). Several significantconcetationsofthegorgonianK. *ornata,* which were thoroughly mixed with *Asconema foliala* (Fristedt, 1887), a fibreglass-like sponge (Wareham & Edinger, 2007; NAFO,2008c; Fulleretal., 2008a; Gilkinson & Edinger, 2009; Murilloetal., 2009)werealsomapped. Sherwood and Edinger (2009) have shown that both *K. ornata* and S. *arcticaexhibit*slowgrowthrates andarelong-livedand,ifdamaged, recoveryfortheseK-strategist species may take

Located in international waters, the Flemish Pass is heavily-fished by many countries (Canada, EU, Japan, Russia, and United States) but effort appears to be focused on the upper (northeast and northwest) and lower (southeast and southwest) edges of Flemish Pass based on Vessel Monitoring System (VMS) data (Murillo etal., 2008). The centre of Flemish Pass, along with the western side of Flemish Cap where it protrudes out into it, isavoidedbyfishers. Theslopeinthisparticularareaissteepandheavily-incisedwith submarine canyons and is considered untrawlable (Antonio Vázquez, **NAFO, personal** communication, Sept. 10,2008). In areas where fishing isneglig*ible, corals(K.ornata,* **S.arctica, andadiversityofseapens)weremappedusingresearchsurveydata** Portions of Flemish Pass (Fig. 4.10&4.17)have been granted interim protection by **NAFO, basedonthesignificantconcentrationsoflong-livedgorgoniansand** antipatharians, andsponges(NAFO, 2008c; Fulleretal., 2008a; Gilkinson&Edinger, 2009; NAFO, 2010). Furtherresearchisneededtoevaluatetheeffectivenessofcurrent closures, to see if they are sufficient in size and location

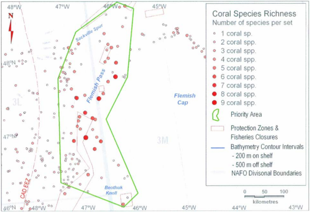

Figure 4.17. Map of Flemish Pass, priority area for future deep-sea coral research. Map illustrates coral species richness which was determined by the number of coral species observed per set from DFO Multispecies Surveys and fisheriesobserversfrom2002to

4.6.5 Southwest Grand Banks (National and International Waters)

The Southwest Grand Banksencompassestheedgeandslopeofthe Canadian continental shelf of the Grand Banks of Newfoundland includingHalibutandHaddock

influenced by warm slope water from the Gulf Stream as it moves across the North Atlantic. Itisanimportantareaforavarietyofdirectedfisheries using primarily fixed-gear types. Most recently, it has been identified as a coral diversityhotspot(Edingeret al" 2007a; Wareham & Edinger, 2007). *In situ* observations from the 2007 DFO ROPOS expedition showed large concentrations of *K. ornata* between 800-1000mdepths, in

colonies(-1 mheightx1 m width) occurred in patches on isolated boulders with other coral species (Anthomastusspp., *Acanthogorgia armata* Verrill 1878, andneptheids) The surrounding area around each patch was predominantly mud substrate and devoid of sessile megafauna. Other unique habitats were observed such as vast sea pen and *Acanellaarbuscula(Johnson*, 1862) fields that spanned 100sofmetres. Quantification of corals and sea pens from video collected during the 2007 ROPOS cruise are currently ongoing(Bakeretal.,2008)

division between depths of 800-2000 m but, unfortunately, does notincludeuniquecoral habitats found at shallower depths during the 2007 ROPOScruise, nor the *Keratoisis* thickets located in NAFOdivision 3Ps to the west of the closure. Ona regional level, the identified EBSAs by DFO for Placentia Bay/Grand Banks LOMAwasexpandedto

thickets were found (Templeman, 2007). The southwest Grand Banks is the only priority area already under partial protection (Fig. 4.18). However, several issues should be re-**examined, suchastheextensionofthecurrentboundarytoinclude** shallower coral habitats identified previously (Wareham & Edinger, 2007) but notincluded in current

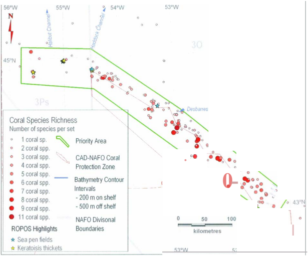

Figure 4.18. Map of southwest Grand Banks, priorityareaforfuturedeep-seacoral research. Map illustrates the currentCAD-NAFO Coral ProtectionZone overlaid with coral species richness. Richness was determined by the number of coral species observed per set from DFO Multispecies Surveys and fisheriesobserversfrom2002to

Since the late 1990s, the Maritimes Region of DFO has made great progress with coral research. This region has documented coral distributions; established several protected areas; perform annual benthic research surveys; and emplaced a Coral Conservation Plan (2006-2010; DFO, 2006b)

Research on corals in the Newfoundland and Labrador Region began in 2003. In this relatively short time, coral biodiversity and biogeographic patterns have been documented and mappec, and novel research focusing on life histories, ecology, biogeochemistry, and relationships to fish has been initiated (see Gilkinson & Edinger, 200g). Priority areas for protection and further research are now identified but, so far, only interim measures have been taken. The next steps are to continue with dedicated research programmes in order to fill information gaps on recruitment, reproduction, and recovery rates; and to assist in the designation of important areas for immediate long-

Compared to other regions in Canada, DFO Newfoundland and Labrador Region face unique challenges regarding marine conservation, including a general lack of understanding and public awareness of environmental issues and processes, and traditional approaches to fisheries management

4.7.1 Public Awareness and Understanding

One challenge for Newfoundland and Labrador Region is the lack of understanding and public awareness on environmental issues and processes related to marine conservation. The economy of Newfoundland and Labrador was/is developed on natural resources suck as fishing, mining, forestry, and more recently oil exploration) Educational programmes are needed to inform the public about envlronmental processes to link nature with the processes of ecosystem functions. This approach would promote conservation awareness, but more importantly build acceptance of the steps required to ensure marine conservation and protection (e.g. MPA process)

The first step would be to assess the level of understanding the publichason conservation issues and determine at what educational level (primary, secondary, etc.)

levels, such as through the school curriculum, government-led programmes(e.g. Hunter Education Courses), orthrough local media outlets (e.g. FisheriesBroadcast, Land and Sea, and VOCM Open Line). For example, at the provincial intermediate school level a marine component was introduced to the Grade Eight science curriculum in 2008. At the high school level an optional Environmental Science Programmehasbeenincorporated into the 2009 curriculum (M. McKeon, Newfoundland and LabradorRegionalSchool District, personalcommunication, Nov. 19, 2009; EasternSchool District, 2009a) **Scientists from DFO were involved in writing sections for the new high school environmental sciences text book (K. Gilkinson, DFO, personal communication, Nov. 3,** 2009),which has been updated to reflect current issues relevant to this province (Eastern School District, 2009b)

For resQurce users like fishers, educational awareness program**mescouldbe** incorporated into licence agreements or as dackside educational programmes (Lien, 1994). In addition, short educational programmes could bedeveloped to help promote environmental issues via local media such as Canadian Broadcast**ingCorporation(CBC)** Land and Sea programme. Material to produce such programmes could be provided by Science Branch generated from local research (e.9. ROPOS Discovery Expeditions). To increase public awareness on local environmental issues and processes related to marine conservation within Newfoundland and Labrador, governmen**t-lededucation** programmes are key

Information on global policies (Le. *UNGA Resolution* 61/105) that affect national and regional issues and actions need to be interpreted anddisseminated to the public. The terminology used in these policies is often foreign to mostreaders and events influencing such policies may not be well known. This is where NGOs (Non-Government Organizations), ENGOs (Environmental Non-Government Organizations) and conservation groups can help. Other regions in Canada have well-established conservation groups (e.g. SIERRAClub, David Suzuki Foundation) and environmental advocacyorganizations(e.g. WorldWildlifeFund, EcologyAction Centre) that play an importantroleasenvironmentalwatchdogs, publiceducators, andpolicytranslators Such groups bridge the knowledge gap between convoluted legislation, policiesand environmental issues. The number of advocacy groups (e.g. Canadian Parks and Wilderness Society, Conservation Corps, MUN Project Green) is growing within Newfoundland and Labrador. Recently World Wildlife Fund (WWF) establishedalocal chapter in St. John's, as well as entered into a Collaborative AgreementwithOFO Newfoundland and Labrador Region to promote a better working relationship and fund futureresearchcollaborations(DFO, 2009c).DepartmentofFisheriesandOceansis also working more closely with other environmental NGOs on conservation issues, as evident by signing a Memorandum of Understanding with members of the coalition of national and regional non-governmental conservation organizations(DFO, 2007c)

However,publicperceptionofenvironmentalactivistsstillremainstaintedbyhistorical conflicts between the public and international animal rightsgroups (e.g. seal hunt protesters). Asa result many Newfoundlanders and Labradoriansdistrustall environmental groups and view them as extremist. Awareness through education and a more "practical" presentation of environmental issues isslowlychanginglocalattitudes For example when whale entrapments were presented to fishers as a fisheries problem and not only as an environmental one, the approach helped provideDFOscientistswith the cooperation needed to resolve the issue (G. Stenson, DFONewfoundlandand

Labrador Region, personal communication, Dec. 8,2009).Thesame approach could be used for by-catch issues related to corals

As 'front line' workers, fishers can also play the roleoftheenvironmentaladvocate voicing concerns related to the sea. A good example of this was seen in the Maritimes where,inNovaScotia,deep-seacoral activismoriginatedwith long-linefishers. These fishers shared their knowledge on deep-sea coral distributionsanddirectedscientiststo the first reported coral-gardens in Canada-nowprotectedwithin the Northeast Channel Conservation Area (Lees, 2002). In Newfoundland and Labradorsome fishers (and observers)havesteppedforward,voicingconcernsaboutthedestructionof 'sea-trees' (w. Bartlett, Newfoundland and Labrador fisherman, personal communication, Oct. 10, 2005). Fishers promote deep-sea conservation awareness bydisplayingmagnificent specimens of large corals caught as by-catch (see Fig. 4.19&4.20). Information fishers provide give scientist invaluable information on historicdistributionsofdeep-seacorals, albeit a snapshot in time (Gass & Willison, 2005; Colpronetal. 2010)

Distributions of corals are being systematically studied in NewfoundlandandLabrador, and eastern Canadian Arctic; however, we know very little about baselineinformation

of anthropogenic impacts on corals; past concentrations of large gorgonianswhich are now limited to only a few areas; as well as maximum size of individual colonies. Local Ecological Knowledge (LEK) has been utilized in previous deep-sea coral studies (Gass & Willison, 2005; Colpron etal., 2010)but needstobe investigated ingreaterdetail(see Cowardetal.,2000; Neis& Felt,2000). Retired fishers, whom have spent their entire

changes of coral by-catch and may be less reluctant to withhold information, which may ostracize them from olhers in the community(S. Fuller, EcologyActionCenlre, Feb. 8, 2009, personal communication)

"Out-of-sight, oul-of-mind" holds true when ilcomesto protection of deep-sea habitats For Newfoundland and Labrador fishers who have spentlheirenlirelifeonthesea, the only concept they have of these deep-water ecosystems is derivedfrom the inlact, or more typically, fragmented pieces of coral brought up in theirfishinggear(Figs. 4.19& 4.20). For the few fishers who have been fortunate enough to see these systems in lheir naturalstate, insiluimagesoftheseafloorensure1.)abetterappreciationofdeep-sea habitat and associated marine life (e.g. corals), 2.)demonstrate the potenlial role of these species in benlhicecosystems, and 3.) most importantly, provide an underslandingofwhytheyshouldbeprotecled. Thisinformalioniscrilical.Mostfishers are unaware of the role that corals play in benthic habitats. Toaskafisherlogiveupa primary fishing area in order to protect corals must appear unrealistic, anddifficultto accepl, when encumbered with the pressures of bills to pay, quotas tomeet,and

Figure4.1g. Examplesofcoralsamplescaughtasby-catchbyalocalNewfoundland and Labrador gillnet fisher; (L-R) *Primnoaresedaeformis*, *Paraborgiaarborea*, *and Desmophyllum dianthus* from Makkovik Bank, Labrador Shelf

Figure 4.20. Examples of coral samples caught as by-catch by local Newfoundlandand Labrador fishers; (L-R)Paramuriceasp. acquired off southern Newfoundland,and Keratoisisornatafrom the northern tip of Sf. Pierre Bank

4.7.2 Traditional ManagementStyles and Advancements

Another challenge for marine conservation has been the traditional management style and views ofDFO. The focus for DFO Newfoundland and Labrador Region, likemost regions, was managing fisheries as individual components (Le. single species stock assessment), andnotviewingtheecosystemasanetworkofintricate links between hierarchical levels. As a result science priorities focused on groundfishsurveys, and availableresourcesforresearchwereallocatedaccordingly. Unlikeotherregions, the Maritimes shifted towards an ecosystem-based approach, including the investment and development of dedicated benthic surveys to complementtraditionalsurveydata

As for Newfoundland and Labrador, with the collapse of the cod fishery, effortwas placed on developing new fisheries utilizing traditional gear types (Roberts, 2007; B Wareham, Newfoundland and Labrador Government, personal communication, Sept. 11, 2008). Fisheries expanded into deeper waters as well as into Canada's eastern Arctic (DFO, 2006a). The proximity of this province to international waters means local issues

necessary, adding additional challenges to managing resources in this region

Nonetheless, we have entered into a new era and management views are slowly changing as efforts are being made to align the region with a national direction (DFO, 2009d). Funding provided through the International Governance Programme (IGP) supported a three-year research project titled the *Newfoundtandand Labrador Deep-Sea Coral Project*. The project focused on deep-sea coral distributionsandbiodiversity, and explored coral biology and ecology, and associated species (see Gilkinson& Edinger, 2009). The project concluded in 2007 with the DiscoveryCruise using the latest deep-sea technology, ROPOS (see www.ropos.com). Additional funding has been providedforfurtherdeep-searesearchoncorals, sponges, andVMES, throughthe InternationalGovernanceStrategy(IGS), underHealthoftheOceansStrategy

Re-allocation of limited resources into essential research areas within the region will take time. One of the greatest challenges relates to region size, in that Newfoundland and Labrador region is significantly larger than any others in Canada. Another is acquiring proper research tools to carry out 'non-destructive or low impact' sampling techniques that will have minimal impact on benthic communities (e.g. ROVs, deep-sea cameras) An initial investment in a Remotely Operated Vehicle (ROV) would be costly but highly beneficial because it has the capability to conduct benthic surveys, map habitats, monitor changes, document impacts, educate the public through video footage, and collect samples whether it be biological, physical, or electronic data (Roberts, 2007, Koslow, 2007, Roberts et al., 2009). These deep-sea ROV cruises are infrequent and are jointly funded through DFO and other agencies (e.g. NSERC). In 2010, ROPOS will be deployed off Newfoundland on the Orphan Knoll, Flemish Cap, and Tobin's Point

Other research options include investing in deep-sea camera systems that can document *in situ* observations in combination with traditional surveys. The Newfoundland and Labrador Deep-sea Corals Project has acquired such a camera system that can document habitats to a depth of 1000 m but lacks the operational funds and dedicated platforms needed to launch it. As funds become available, the project team anticipates using the system, along with other tools, to ground-truth candidate VMEs. Acquiring modern sampling tools and reliable platforms are basic necessities for deep-sea research. However, these tools can be used in many different environments, not just the deep-sea. This is especially important in Newfoundland and Labrador; to replace traditional methods of trawl surveys currently being used

Recently, DFO Newfoundland and Labrador has made advances in adopting an ecosystem approach through broadening research areas and methodologies. Research surveys, which have traditionally targeted commercial species, have been expanded to include non-commercial species including megafauna such as cor**alsandsponges(e.g** NEREUS Programme; Appendix 4). Newfoundland and Labrador's ExpandedResearch on Ecosystem-relevant but Under-surveyed Splicers (NEREUS) was implemented in the fallof2007, and isa new Ecosystem Research Initiative (ERI) for the Newfoundland and Labrador Region. This programme will contribute data, promote the ecosystem approach, andhelpanswerimportantquestionsaboutenergyflows, andpathwaysin shelf marine ecosystems in the region

Deep-sea coral by-catch data are regularly collected in most Canadian waters and were used to map distributions (Wareham & Edinger, 2007; Wareham, 2009) and areas of high concentrations of corals *off* eastern Canada (Wareham, 2010). The Newfoundland and Labrador Deep-sea Corals Programme has expanded in 2008 to inc1udethe collection of deep-sea sponge data and is investing in localtaxonomic expertise on sponges. In addition, digital cameras have been issued toall Newfoundlandand Labrador fisheries observers to aid with species identification an**ddocumentationof** sponge by-catch at sea. Similarspongedatasets have been developed and utilized in theAtianticCanada(Kenchingtonetal., 2010; Warehametal., 2010), andotherscould be easily developed in a similar manner (e.g. bryozoans and hydroids). Once developed, datasetsoncoral, spongeandothermegafaunacouldbecombinedin order to help scientist identify important areas of high biological diversity, **aswellasassistresource** managers in delineating areas for protection

Scientistsintheregionareinvolvedininter-regional, nationalandinternationalworking groups related to identifying VMEswithin Canada's EEZ and the NRA;developing national coral-sponge encounter protocols, and drafting a Newfou**ndland, Labradorand Arcticcoral-spongeconservationstrategyforthenorthwestAtlantic. Aswell, theregion**

is now home for two new national centres: Centre of Expertise (CoE) inAquaticHabitat Research(CAHR;DFO, 2009f), andtheCoEinColdWaterCoralsandSponge Reefs (DFO, 200ge). The CoE in Cold Water Corals and Sponge Reefs has released the Status Report on Coral and Songe Conservation in Canada (Campbell & Simms, 2009), which will be used to help development the conservation strategyfor the northwest Atlantic. Currently, the Maritimes Region has a strategy in place which will be revised in 2010 and it is anticipated that there will be strong similarities between the two strategies

immediate urgency to protect important areas and VMEs that are currentlyunderthreat from bottom fishing. Marine Protected Areas offer the highest level of protection but the **process of establishing MPAs is complex and time-consuming. Immediate closures are** needed and can be implemented under the *Fisheries Act.* Managementdecisionsshould be based primarily on scientific data with socio-economic considerations coming second

Another challenge with traditional management styles is how we conduct business; namely, howwefish. Trawlin9, alsoreferredtoasdra99in9, isgenerally viewed by the scientific community as one of the most destructive methods of fishing (Morgan & Chuenpagdee, 2003; Fulleretal., 2008b; Robertsetal., 2009). Itis indiscriminate; targetsallspeciesfoundinthetrawls' path, andthreatenswhole habitats and ecosystems in the area swept(DFO, 2006d; Rice, 2006; Gordon eta1.,2006). Thereare parts of the world where trawling is now banned (WWF, 2005a, 2005b; Associated Press, 2005; Pennyetal., 2009). However, the government of Canada still permits **trawling but is working with industry to better understand the environmental impacts of** suchfishinggear(DFO, 2006c)

In the Newfoundland and Labrador and Arctic regions, trawling continues to be the most-frequentfishingmethod(Fulleretal., 2008b). Thebasicprincipie of trawling has not changed since its introduction in the early 1900s. Slight gear modifications have been made to increase its versatility and effectiveness (e.g. rock hopper gear) as well as adaptations to reduce by-catch (e.g. NordmoreGrate, Turtle Exclusion Devices) **However, no modifications have been implemented to reduce the impact on the sea floor** and the organisms that inhabit it (e.g. deep-sea corals and sponges). There is ongoing research at the Marine Institute (MUN) to reduce bottom contact 0ftrawlnetsbyflying

marketed (P. Winger, Marine Institute, personal communication, Nov. 12, 2008). Roberts (2007) states it best: "bottom trawl nets will always crush and sever bottom-living species like corals. The only solution for this gear is to ban itcompletely, orgreatlyrestrictwhere it can be used". The latter may be the best hopeforprotectingandconserving deep-sea corals in the Newfoundland and Labrador region, especially as fisheries utilizing trawl gear expand into Canada's arctic. In NewZealand, fisheriesmanagers have been successful in controlling where bottom gear is used, with trawls restricted to areas previously fished while virgin areas are off-limits (Penny et al., 2009)

Fixed gears (e.g. longline, gillnets, and crab pots) used in this region have been shown to capture corals (Wareham & Edinger, 2007; Edingeretal., 2007ab), butthistypeofby-**catch could be reduced with minor gear modifications. For example, if crab pots were** singularlydeployed, as in the Alaska crab fishery (Alaska Departmentof Fish & Game, 2009),itwouldreducethedragofthegearacrosstheseafloorduringbothdeployment

entanglementsinfixedgear(Volgenauetal., Igg5;Lien, 1994) reportedbycrabfishers

Thisisjustoneexampleofhowby-catchcanbereducedbyalteringhowwefish Further research is needed to investigate additional options

With the establishment of MPAs in eastern Canada, progress has been made to protect deep-sea corals. Strategies used for each area were discussed. Aswell, priorityareas within NewfoundlandandLabradorwereidentified.Uniquechallengeswerereviewed and recommendations were suggested as potential solutions. To reiterate, several

First, even with these protection efforts, there is still an urgent need to identify and protectVMEsin Newfoundland, LabradorandArcticregions. Coral distributions are now being consistentlydocumented,and several locations identified for *in situ* research have been explored. Nevertheless, this region continues to lag behind others when it comes to permanent protective measures (Le. MPAs). The process of MPA selection and designalionis lengthy and complex. However, for highly-disputed areaslhe *Fisheries Act* may be the besl conservalion tool to prevent further damage, especiallypriortoanMPA designation, as seen in the Darwin Mounds Closure (see Robertsela1., 2009). Several candidate VMEs (e.g. Hatton Basin) could be closed immediately **with** minimal socio-economic impacts due 10 the lack of fishing in these areas. Forlhe Hatton Basin, the volunlaryclosureisagoodfirslstep, but legislation is urgentlyneededtofullyprolect long-lived species found inside and outside the presentclosure. These coral species are highly sensiliveto bottom fishing dislurbances(Kreiger, 2001), andareamongthe 10ngestlivedspeciesofcoralfoundintheregion(Sherwood&Edinger, 2009)

Second, istheimportanceofDFO investingindedicatedbenthicresearchprogrammes (e.g. corals, sponges, habitat mapping using multibeam). Theregionhasmade substantial progress with the Newfoundland and Labrador Deep-sea Corals, and NEREUS Programmes. However, these programmes are largely dependant on short-term funding (albeillong-termobjectives)and opportunisticsamplingonotherdedicated surveys. Information gaps on recruitment, recQveryrates, historic abundances and diversity of deep-sea corals are key areas of research. Tofillsuchgaps, long-term **studiesarerequiredwithdedicatedsupportandresQurces. Rese**arch is needed on gear **modificationstoreduceoreliminateimpactsontheseafloor.DepartmentofFisheries** and Oceans Canada is providing ongoing funding for VMEs and coral researchvialGS but additional capital investments toward modern technologies (e.g. ROVs, drop camera

good science

Third, istheimportanceofcollaborationsand/orintegratedmanagementamongst institutions; nationally and internationally. The cost of deep-sea research maybe more than one organization or institution has the capacity to carry. Therefore, it is

example, DFOiscurrentiyengagedinatwo-yearinternationalcollaboration on the high **seas to map the sea floor using multibeam sonar, combined with ground-truthing (i.e** benthic sampling using box cores and dredges). The objectives 0fthis project are to identify potential VMEs and to assess impacts of deep-sea fisherieswithintheNRA focusing on Flemish Cap, Flemish Pass, Beothuk Knoll, and the noseandtailofthe Grand Banks (DFO, 2009g). In 2010, DFO (Newfoundland and Labrador, and Maritimes Regions) will collaborate again with MUN on a deep-sea expedition toOrphanKnoll, off northeast Newfoundland to compare physical and biological characteristicsofthis unique seamount with the adjacent continental shelf slope habitats (e.g. Orphan Spur)

Other projects and collaborations are being developed, which will include ENGOs such asWWF(DFO, 2007c, 2009c)

For policy planning, collaborations within DFO will be important. For example, the Newfoundland and Labrador Coral and SpongeStrategy, withsupportbyEcological Risk Analysis Framework will be key in future conservation measures for corals and sponges. Another important collaboration is the Canada Newfoundland and Labrador Offshore Petrolum Board and DFO Habitat Management, to help protect corals and identify candidate VMEs from non-fishing activities (e.g. oil and gas exploration)

The final step necessary to successfully achieve coral protection in Newfoundland and Labradorisaparadigm-shift ofhowthepublicperceivesDFO andits role as managers of the ocean. Getting the public and industry onside will be the most difficult, but crucial part. It will require hard work and diligence through education programmes, transparency **in management agendas, and communication campaigns to promote collaborative deep-**

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APPENDIX 1: SYSTEMATIC LIST OF THE PHYLUM CNIDARIA: CLASS ANTHOZOA NEWFOUNDLAND AND LABRADOR, AND BAFFIN ISLAND, CANADA

SystematiclistofthePhylumCnidarian: ClassAnthozoaforalispecies documented off Newfoundland, Labrador, and southeast Baffin Island regions: speciesdocumentedare in '*bold*. Species documented more recently but not mentioned in this body of work are highllighedwith '·'. ListisbasedonIntegratedTaxonomicInformation System (ITIS) for the exceptions of *Paraslenelfa atlanlica* listed under the UNESCO-IOCRegisterof Marine Organisms (URMO), and *Heleropofypus* sp. listed under World Register of Marine Species (WoRMS)

PhylumCnidariaHatschek, 1888

Order Scleractinia Bourne, 1900 - stoneycorals
SuborderCaryophylliina Vaughan and Wells, 1943
SuperfamilyCaryophylliicae
FamilyCaryophylliidaeDana, 1846
***Dasmosmilialymani** Pourtales, 1880*
Desmophyllum dianthus (Esper, 1794)
·***Lophelia pertusa*** (Linnaeus, 1758)
Vaughanella margaritata (Jourdan, 1885)
Family Flabellidae (Bourne, 1905)
***Flabellumalabastrum** Moseley, 1876*
·***Flabellumangulare** Moseley, 1876*
***FlabellummacandrewiGray**, 1849*
***Javania cailleti**(Duchassaing* & Michelotti, 1864)
Subclass Ceriantipatharia *Van* Beneden, 1989
Order Antipatharia Milne-Edwards and Hairne, 1857-blackandthornycorals
Family Antipathidae Ehrenberg, 1834
·***Stichopathes** sp*
***Bathypathes** sp*
Family Schizopathidae Brook, 1889
Stauropathes arctica (Lutken, 1871)

SubclassOctocorallia Haeckel. 1866

OrderAlcyonaceaLamouroux. 1816-softcorals

SuborderAlcyoniina-true softcorals

FamilyAlcyoniidaeLamouroux. 1812

Anthomastusgrandiflorus Verrili
Anthomastu5cf. purpureu5
Anthomastusagaricu5
'Heteyopolypus sp
'Drifaglomerata (Verrill. 1869)
Duva florida (Rathke, 1806)
Duva multiflora Verrill
Gersemiafruticosa
Gersemia rubiformis (Ehrenber9. 1834)

SuborderCalcaxonia

FamilyIsididae Lamouroux. 1812

Acanellaarbuscula (Johnson. 1862)
Keratoisisornata (Verrill. 1878)

FamilyPrimnoidae

Primnoa resedaeformis (Gunnerus. 1763)
'Parastenellaatlantica Cairns. 2007(seeURMO)

Suborder Holaxonia Studer. 1887

Family Acanlhogorgiidae Gray. 1859

Acanthogorgia armata Verrill. 1878

Family Chrysogorgiidae Verrill, 1883

Chysogorgiaagassizii Verrill, 1883
Radicipesgracilis Verrill, 1884

Family PlexauridaeGray, 1859

Paramuriceagrandis Verrill, 1883
Paramuricea placomus (Linnaeus. 1758)

SuborderScleraxoniaStuder. 1887

Family Anthothelidae Broch. 1916

Anthothela grandiflora (Sars. 1856)

FamilyParagorgiidae

Paragorgia arborea (Linnaeus. 1758)
Paragorgiajohnsii

Order Pennatulacea Verrill, 1865 - seapens

Suborder Sessilifiorae Kukenethal, 1915

Family Anthoptilidae K6l1iker, 1880

Anthoptilum grandiflorum (Verrill, 1879)

Family Funiculinidae Lamarck, 1816

Funiculina quadrangularis (Pallas, 1766)

Family Kophobelemnidae Asbj0rnsen, 1856

Kophobelemnon stelliferum (Muller, 1776)

Family Ombellulidae Williams, 1995

Umbellula lindahli (K61liker, 1875) (=Ombellula)

Umbellula encrinus (Linnaeus, 1758) (=Ombellula)

Family Protoptilidae K6l1iker, 1872

Distichoptilum gracile (Verrill, 1882)

Protoptilum carpenteri K6l1iker, 1872

Suborder Subseilifiorae Kukenethal, 1915

Family Halipteridae Wiliiams, 1995

Halipteris finmarchica (Sars, 1851)

Family Pennatulidae Ehrenber9, 1828

Pennatula aculeata Danielssen, 1860

Pennatula borealis M. Sars, 1846 (=P. grandis)

Pennatuia phosphorea Linnaeus, 1758

Family Vir9ulariidae Verrill, 1868

**Virgularia mirabilis (Muller, 1776)*

Cairns, S.D. (2007). Studies on Western Atlantic Octocoraliia (Octocorallia Primnoidae). Part 8 : New records of Primnoidae from the New En91and and Corner Rise Seamounts. Proceedings of the Biological Society of Washington, 119(2),243-

Integrated Taxonomic Information Systems (2010). URL: http://www.itis.gov/index.html

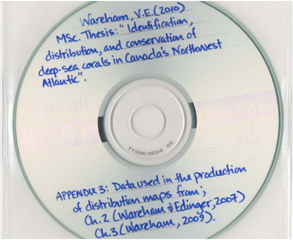
UNESCO-IOC Register of Marine Organisms (2010). URL http://www.marinespecies.org/urmo/index.php

World Register of Marine Species (2010). URL: http://www.marinespecies.orglindex.php

APPENDIX 2: IDENTIFICATION GUIDE TO DEEP-SEA CORALS

NEWFOUNDLAND LABRADOR, AND BAFFIN ISLAND, CANADA

APPENDIX 3: DISTRIBUTION MAPS AND DATA USED IN THE PRODUCTION OF MAPS FROM CHAPTER 2 (WAREHAM & EDINGER, 2007) AND CHAPTER 3 (WAREHAM, 2009)



Compact Disk includes; distribution maps (PDF format), data used in maps (Microsoft Excelformat),and identification guide to deep-sea corals (PDF format)

NEWFOUNDLAND, LABRADOR, AND BAFFIN ISLAND, CANADA

Department of Fisheries and Oceans
Deep-sea Coral Collection Protocol

Deep-Sea Coral Collections:

The following isa general collection protocol for all corals encounteredduring allDFOandpartnershipsurveys

Note: coral data (weights and species codes) are to be entered into the FFS database at sea

- Identify all corals to species level and assign a DFO species code with the aid of the ***Newfoundland Labrador Deep-sea** Coral Identification Guide*. If a sample is unidentified or uncertain, code as '8900'
- Record total weight of corals by species
- Place individual coral species in separate bag along with a labelied waterproof tag, and freeze. Whenwritinglabelsuseonlyaballpointpen or pencil in order to prevent smudging of ink on label when wet

Protocol for unique circumstances:

- For large corals take a picture of the enlire sample with a scale(i.e. ruler, hand, coin,etc.), anda label which must be placed in the photo Always review photos to ensure clarity of each label in each photo. There will be a corallsponge camera assigned to every survey trip (see the Chief ScientistITechnician for access of the camera)
  - o Iffreezerspaceisavailablefreezeentirespecimen
  - o If freezer space is limited or the coral is too large for the chute, recordtotalweight, thencuta subsample(>ZOcm)from both the base and tip of the specimen and bag, tag & freeze: it would be desirable to store the remainder of the specimen somewhereonthe vessel if possible
- If a set has numerous small pieces of one species (i.e. cauliflower coral), separate out to the best of your ability, and record total weight. Freeze only a smallsubsample(-Z-3 pieces) of the total catch

October 1, 2009

Department of Fisheries and Oceans
Sponge Collection Protocols (NEW)

Sponge Collections:

Spongesalongwilhcoralsarenowconsideredimportanlcomponentsof Vulnerable Marine Ecosyslems (VME) and are of particular inlerest 10 DFO, especiallyquanlifying levels of abundance and determining speciesdiversily Sponges are nowcollecled alsea on all mullispeciessurveys. However, spongeidenlificationisdifficull, lhereforenospeciesidenlificalionisrequired at sea. Inslead all sponges will be ***separated by visual differences only*** and represenlative samples of each lypewill be kepi and frozen.

Tohelpdelermineabundancelevelsofsponge, acamerawillbeassignedlo eachsurveyvesselforlhepurposeofphlographinglargecatchesof sponges, especially when large spongecatchesaredisposedofondeckand nolprocessedinlhewetlab

Each camera will be the responsibililyoflheChiefScientisVTechnicianin charge of each lrip, and ilislheirresponsibilily lorelurneach cameraloeilher Bill BrodieorVondaWareham altheend of each trip. Ifalripisterminaled in another port besides St. John's il is the responsibililyoflhe Chief ScientisVTechnician to assign lhecamera 10 the nexlperson in charge, or ensure lhecamera isrelurned toeilherBili orVonda

The following is a general colleclion prolocol for all spongesencountered during all DFO and partnership surveys. Pleasefollowsteps in sequencelo ensureappropriaIeinformalionisgalheredforspeciesidentification

1. Normal Sets: separate all sponges by ***visual differences only*** into separalebaskets: combineallsub-weighlstodelerminelotalcalchofall spongeand recordinFFSdalabase
2. Normal Sets: bag separalely 1 represenlalive sample of each sponge lypeinorderlodocumenlspongediversily
   - Label each ***sponge type*** as A, B, orCand place all represenlalive samples of each ***sponge type*** from the same seltogetherin a secondarybagwithlrip/selnumber
   - Note on catch/set sheet if only 1 species was captured inlotal catch.
   - ***Ifspaceislimiting*** *asubsample oflherepresenlalivesample can* belaken. However, subsamplesmuslconsislofacross-seclion of the sponge in order to adequalely samplelissue from lhe core and theexlernalpartoflhesponge, whichcandiffer.

Sponge Collection Protocol continued:

3. <u>Large Sponge sels:</u> For large sponge sels lhal are shovelled offlhetrawl deck and nOlprocessed below in lhewellab, lhefollowingslepsmuslbe laken;
   - *Estimate the totalweightoflhe* sponge catch using the aclual weighlofalleasl1 represenlalivesample
   - *Recordtotalweightonse Vcalchdecksheelandmakenoleoflhe* number of species
   - ***Photography total catch* on *deck WITH;***
     - *label(trip/setwrilten* large and clearly on cardboard}
     - *scale* (i.e. person, lrawldoor, elc.}
     - subsample (idenlifybyplacinginbaskel)

   NOTE: labelsmust beplacedinthephotos (i.e.ausealargepiece of cardboard with lrip/sel#) and writing musl be large enough to see from a dislance. Preview each pholoto ensure readabilily of label

Tips for success: forconsislency assign 1 individual per shift lo cover sponges including responsibility of camera. When pholographin9 sponges on deck use lhefollowing guidelines;

- ✓ Notify deck crew of sponge prolocol especiallywilh large catches
- ✓ Befamiliarwith lhecameraa headoflime
- ✓ Be prepared and have cardboard labelsreadywilh marker on deck
- ✓ Labels musl be large enough to see from a distance and include trip/setnumber
- "/Useascaleineachpholo(i.e. personholdinglhe label}
- ✓ Most importantly preview all pholos for clarily especially legibility of label

For further informalion conlacl
Bill Brodie (709}772-4718 bill.brodie@dfo-mpo.gc.ca
KenlGilkinson (709}772-4718 kent.gilkinson@dfo-mpo.gc.ca
Vonda E. Wareham (709) 772-2804 vonda.wareham@dfo-mpo.gc.ca