INCIDENTAL CATCH OF LARGE MARINE VERTEBRATES IN GILLNET FISHERIES IN NEWFOUNDLAND AND LABRADOR

STEVEN BENJAMINS

Your file Votre référence
ISBN: 978-0-494-42109-3
Our file Notre référence
ISBN: 978-0-494-42109-3

INCIDENTAL CATCH OF LARGE MARINE VERTEBRATES IN GILLNET FISHERIES IN NEWFOUNDLAND AND LABRADOR

by

Steven Benjamins

A thesis submitted to the

School of Graduate Studies

in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

Cognitive and Behavioural Ecology Programme

Memorial University of Newfoundland

September 2006

St. John's Newfoundland

Abstract

Small cetaceans, such as harbour porpoises, often become entangled in gillnets, and this anthropogenic mortality is a conservation concern. For years, harbour porpoises have been captured regularly in fisheries in waters of Newfoundland and Labrador (Canada), but defendable estimates have been lacking. Incidental catch of small cetaceans in nearshore and offshore gillnet fisheries in Newfoundland and Labrador waters was studied for the years 2001, 2002 and 2003, using datasets from Fisheries and Oceans Canada, reports from fishers, and Fishery Observer records. Fisheries studied included those targeting Atlantic cod, lumpfish, Atlantic herring, monkfish, white hake, Greenland halibut, redfish and winter flounder.

A methodology was developed to estimate incidental catch, based on datasets currently available within the Department of Fisheries and Oceans. Confidence intervals were generated using resampling statistics, allowing an assessment of uncertainty surrounding these estimates. Despite reductions in fishing effort since 1992, an estimated average of 1,516 harbour porpoises were captured in various Newfoundland and Labrador gillnet fisheries annually between 2001 and 2003. Most captures occurred in nearshore fisheries for Atlantic cod and lumpfish. Several dolphin species were also captured in smaller numbers, mostly in the offshore monkfish fishery. The impact of this mortality on

the population of harbour porpoise and other small cetaceans cannot be assessed until population estimates become available.

Using the same methodology, incidental catch assessments were compiled for numerous species of pinnipeds, seabirds, sharks and bony fish that had been reported as incidental catch. For most species, insufficient information exists to assess the impact of this mortality. However, catch rates of harbour seals, murres, shearwaters, various shark species and sturgeons appear to warrant concern.

In conclusion, Newfoundland and Labrador gillnet fisheries annually remove considerable numbers of non-target large marine vertebrates from the local marine ecosystem. The nearshore fisheries for Atlantic cod and lumpfish, and the offshore fishery for monkfish, appear to capture the greatest diversity of species, including small cetaceans, various seals, murres, shearwaters, schooling sharks and sturgeons. Various potential measures to mitigate this incidental catch in Newfoundland and Labrador are discussed. A framework for assessing the impacts of fisheries on marine environments is described.

Acknowledgements

The results of small cetacean incidental catch analyses for the 2002 nearshore Atlantic cod fishery, as described in Chapter 3, were previously published as Lawson *et al.* (2004). The remainder of the results are as yet unpublished, but will be published in the near future. Financial support for this research was provided by the Department of Fisheries and Oceans (DFO), in order to assess the status of harbour porpoise in Newfoundland and Labrador waters under Canada's Species At Risk Act.

This study could not have been completed without the help and assistance from a wide range of people. First and foremost, I would like to thank Dr. Jon Lien (MUN) for his unflagging support, stimulating discussions, and generous hospitality throughout these years. I am also deeply indebted to Dr. Jack Lawson (DFO) for the support and encouragement he has given me, as well as for the many things I learned from him about practical marine mammal research and government bureaucracies. Dr. Garry Stenson (DFO) was always available when I had questions about marine mammal research, for which I am very grateful. Dr. Catherine Hood (formerly DFO) supported me throughout this study, and provided many improvements to the final manuscript. I hope I will someday become as good a teacher as her. Dr. David Schneider (MUN) provided invaluable support in the final stage of the study, and was kind enough to spend long hours helping me to improve upon the structure of the final thesis. I am very grateful for all his assistance and suggestions. Dr. Becky Sjare (DFO) provided much-needed help while I was analyzing seal incidental catch data.

Within DFO, my thanks go out first of all to the Research Technicians within the Marine Mammal Section for all their help and support. Wayne Penney showed me most of rural Newfoundland during a six-week road trip, and taught me much about nearshore fisheries and interviews with fishers. Dave McKinnon, Dennis Wakeham, Bonnie Stockwood, Tonya Wimmer, and Dena Wiseman provided critical information and support during various stages of this study, especially while I was ageing porpoise teeth.

The assistance of many other DFO employees was vital to the completion of this study. Dr. Veronique Lesage (DFO-Quebec) graciously provided Sentinel fisheries data to complement our Newfoundland dataset. Dr. Mariano Koen-Alonso (DFO-NL) helped me understand the vagaries of resampling statistics. Annemarie Russell and Sandra Savory (DFO-NL) granted me access to DFO's Fish Landings and Catch-Effort databases, and were more than helpful in supporting my efforts in understanding its intricacies. Dr. Dave Kulka (DFO-NL) generously provided me with the Fishery Observer records concerning sharks and seabirds. Joe Firth and Carolyn Miri (DFO-NL) were always very patient when I requested yet another selection of the Fishery Observer dataset from them, and taught me much about the nature of the programme. Dr. Rick Stead and Dr. Dawn Maddox-Parsons (DFO-NL) provided access to the DFO Sentinel Fishery database and patiently put up with my questions. Jacqueline Cobbs-Kean (DFO-NL) provided access to the DFO Licensing database, which allowed me to begin to understand the distribution of fishing effort in this province. Finally, Eugene Murphy (DFO-NL) provided access to the Groundfish Effort database, which proved vital in my analyses of cod fishing effort. Mr. Greg Mullett of Seawatch, Inc., was very helpful in explaining to me how the Fishery Observer data was collected. I am deeply grateful to them for all their efforts.

I also wish to express my sincere gratitude to all fishers and Fishery Observers who collected the data upon which this thesis is based. The degree of detail present in their datasheets was often astounding, and provided the basis for new questions. It is my hope that this cordial and productive relationship between fishers, observers and researchers be maintained and strengthened in the future.

As a student at Memorial, I received encouragement and support from several sources. Dr. Anne Storey, as head of the Cognitive and Behavioural Ecology (CABE) programme, ensured that I was quickly integrated into student life here, and gave me sound advice on many occasions. Maureen Howard (Psychology) helped me on numerous occasions to sort out administrative or financial difficulties. Gail Kenney (CABE) was very helpful and efficient in dealing with administrative hurdles surrounding the submission of this thesis.

During these years, I have been fortunate enough to share the Whale Research Group building with three fellow students. Claudio Corbelli, Patrick Abgrall and Hope Brock were my partners in crime, and I am grateful for their friendship and support during these years. I particularly owe a debt of gratitude to Claudio, for his Italian hospitality during the first three years of my stay here in Newfoundland, and for introducing me to the best Newfoundland has to offer.

I would hereby like to thank my parents, Harm and Marijke Benjamins, and my brother Tom, for all the support they have given me throughout this long and laborious process. This period has been one of separation interspersed with a few, all too brief visits. Although Newfoundland has become a second home to me, I have missed my family deeply, and now look forward to spending more time with them in the near future.

Finally, I wish to thank my fiancée Vicki Milway, for everything she has done to encourage me to continue on this path. Her support and good cheer have been essential during these past years. I look forward to spending the rest of my life with her, and it is to her I wish to dedicate this thesis.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CEAA	-	Canadian Environmental Assessment Agency
CeTAP	-	Cetacean and Turtle Assessment Programme
CEC	-	Commission of the European Communities
C.I.	-	Confidence Interval
COSEWIC	-	Committee on the Status of Endangered Wildlife in Canada
DIFRES	-	Danish Institute for Fisheries Research
DFO	-	Department of Fisheries and Oceans
EAF	-	Ecosystem Approach to Fisheries
EEM	-	Environmental Effects Monitoring
EEZ	-	Exclusive Economic Zone
ESSIM	-	Eastern Scotian Shelf Integrated Management
EU	-	European Union
FAO	-	Food and Agriculture Organisation of the United Nations
FRCC	-	Fisheries Resource Conservation Council
GLG	-	Growth Layer Group
ICCAT	-	International Commission for the Conservation of Atlantic Tunas
ICES	-	International Council for the Exploration of the Sea
IHP	-	Incidental Harm Permit
ITQ	-	Individual Transferable Quota
IUCN	-	International Union for the Conservation of Nature
IUU fisheries	-	Illegal, Unregulated or Unreported fisheries
IWC	-	International Whaling Commission
LME	-	Large Marine Ecosystem
LOMA	-	Large Ocean Management Area
MMPA	-	Marine Mammal Protection Act
MPA	-	Marine Protected Area
NAFO	-	Northwest Atlantic Fisheries Organisation
NAMMCO	-	North Atlantic Marine Mammal Commission
NL	-	Newfoundland and Labrador
NMFS	-	National Marine Fisheries Service
NRC	-	National Research Council
PBR	-	Potential Biological Removal
pers. comm.	-	personal communication
SARA	-	Species At Risk Act
SCANS	-	Small Cetacean Abundance in the North Sea
UN	-	United Nations
UNCLOS	-	United Nations Convention on the Law of the Sea
US	-	United States

List of Appendices

CHAPTER 1 - INTRODUCTION: THE PROBLEM OF INCIDENTAL CATCH IN FISHERIES

1.1 - Incidental Catch: A Global Overview

Currently, the bycatch (also called incidental catch) of non-target species during fishing operations is considered to be one of the most important problems facing fisheries management agencies around the world (e.g. Alverson *et al.* 1994; Bjørge *et al.* 1994; International Whaling Commission [IWC] 1994; Dayton *et al.* 1995; Alverson and Hughes 1996; Hall *et al.* 2000; Read *et al.* 2003; FAO 2004; Tudela 2004). Finding ways to reduce incidental catch requires a broad inclusive approach, involving stakeholders from the fishing industry, academia, conservation organizations, management agencies, and the general public.

At its most basic level, capture of unwanted (i.e., non-targeted) species during fishing operations occurs because fishing methods and gears are not perfectly selective (Clucas 1997). According to Hall (1996), bycatch is "that part of the capture that is discarded at sea, dead (or injured to an extent that death is the result). Capture, in turn, means all that is taken in the gear. The capture can be divided into three components: (a) the portion retained because it has economic value (catch), (b) the portion discarded at sea dead (bycatch), and (c) the portion released alive (release)." The portions discarded dead and released alive can involve members of the target species if they are damaged or are of the wrong size, but the focus is usually on other species that are caught incidentally to the target species.

Whether any species caught in fishing gear is retained or discarded varies between individual fisheries, between different fishing cultures, and even when comparing current fishing practices with historical data from the same fishery. Fishers determine which portion of their capture they consider incidental catch and may wish to discard based on a variety of factors. According to Clucas (1997), these considerations may be:

- Wrong species, size, or sex of the caught species;
- Damage to caught species due to abrasion by the fishing gear, mishandling by the fisher, or predation/scavenging by other animals;
- Incapacity to store caught species together with the remainder of the catch for reasons of quality control (e.g. due to rapid spoilage, which might lower the value of the remainder of the catch);
- Inedible, poisonous, or otherwise hazardous or undesirable nature of the caught species to the fisher;
- Lack of space on board (especially in small vessels, but also in large vessels that already have a large amount of fish on board);

- Preferential discarding of a marketable species in order to retain the same species at a larger size and price, or to retain another species of higher value (known as "high grading"; Hall *et al.* 2000);
- Quotas for the caught species (or for another species) have been reached, and landing the excess catch would result in penalties;
- Capture in prohibited areas, using prohibited gears, during a prohibited period, or of species whose capture itself was prohibited, usually on conservation grounds.

Currently, incidental catch receives a large amount of attention mainly because it is perceived as wasteful, due to the high mortality associated with the process. The survival rate of the incidental catch depends on the species involved, the depth at which they were captured, the duration of fishing, the gear type, and the way catches are handled by the fisher, among various other factors. In practice, the survival chances of most organisms caught in fishing gear are limited, and additional mortality may take place some time after release as a result of injuries sustained during capture (Alverson *et al.* 1994; Clucas 1997). Many marine species are also at risk from entanglement in discarded or lost fishing gear, although the extent of this "ghost fishing" is largely unknown (Templeman 1966; Kaiser *et al.* 1996; Reeves *et al.* 2003).

Although incidental catch has been a part of fisheries for thousands of years, current globally high and increasing levels of fishing effort, combined with recent advances in fishing technology, have significantly increased the impact of this phenomenon on wild populations of a large number of marine species (Hall *et al.* 2000). At the same time, public perception of incidental catch and discards has shifted, and the practice is now widely regarded as unethical, economically wasteful, and potentially highly disruptive to populations of marine species and entire marine ecosystems (Hall *et al.* 2000).

Only recently have there been attempts to quantify the global extent of the incidental catch problem. Initial estimates of global incidental catch, based on data from the 1980s and early 1990s, were calculated under the auspices of the United Nations' Food and Agriculture Organization (FAO) by Alverson *et al.* (1994), who reported an average global annual estimate of 27 million metric tons (mt), with a range of 17.9 to 39.5 million mt. This was thought to represent approximately one quarter of the estimated total global landings of marine fisheries at the time (approximately 100 million mt). Later studies have revised this estimate downward, and current best estimates now place average annual global incidental catch at approximately 8 million mt, out of a total landed catch of approximately 93 million mt (FAO 1998, 2004).

Several reasons for this apparent reduction have been suggested, including a change in incidental catch estimation methodology, as well as uncertainty about the accuracy of reported fish landing data from several sources. Possible explanations for an actual reduction in incidental catch include introduction of new fishing gears and practices, improved legislation, introduction and/or expansion of observer programmes, and stronger enforcement of existing regulations. An alternative possibility is that the fraction of total catch that is brought to market by fishers has increased, finding use for those species or age-classes that were previously discarded (FAO 2004). This development may either be caused by an increased awareness of the utility of previously discarded species, or brought about by a decrease in abundance of other more desirable species, or possibly a combination of the two.

1.2 - Marine Mammal Incidental Catch

Although the vast majority of incidental catches involve fish and invertebrate species, it is the incidental capture of species of marine megafauna such as marine mammals that has helped focus significant public attention on the problem. Incidental catch in fishing gear can potentially pose a significant risk to these species because of their long life span and typically low fecundity, which renders their populations vulnerable to sudden increases in mortality rates (Hall *et al.* 2000; Lewison *et al.* 2004). One of the first cases brought to the attention of the public involved the interactions between the U.S. tuna purse seine fleet and various pelagic dolphin species (genus *Stenella*) in the eastern tropical Pacific during the 1960s and early 1970s. This fishery exploited the close association between schools of various species of dolphins and yellowfin tuna (*Thunnus albacares* Bonnaterre), resulting in an annual mortality of several hundreds of thousands of dolphins (Gosliner 1999; Hall *et al.* 2000; Lennert-Cody *et al.* 2004). The public outcry in response to this incidental catch was a contributing factor in the establishment of the United States Marine Mammal Protection Act of 1972. The levels of dolphin mortality in this fishery have since dropped significantly due to changes in fishing practices, and marine mammal mortality in the U.S. tuna fishery is not currently considered to be an overriding conservation concern (Hall *et al.* 2000; Reeves *et al.* 2003).

However, incidental catches of other marine mammal species, as well as seabirds, seaturtles and sharks, have subsequently been identified in many commercial fisheries world-wide, including gillnets, driftnets, trawls, longlines, and fish traps (e.g. Lear and Christensen 1975; Ohsumi 1975; Northridge 1984, 1991; IWC 1994; Jefferson and Curry 1994; Alverson and Hughes 1996; Bravington and Bisack 1996; Palka *et al.* 1996; Tregenza *et al.* 1997a, 1997b; Caswell *et al.* 1998; Tregenza and Collet 1998; Morizur *et al.* 1999; Northridge and Hofman 1999; Silvani *et al.* 1999; Trippel *et al.* 1999; Vinther 1999; Bjørge *et al.* 2002; Manly *et al.* 2002; Reeves *et al.* 2003; Lewison *et al.* 2004; Neimanis *et* *al.* 2004; Tudela 2004; Dawson and Slooten 2005). In the United States, the Marine Mammal Protection Act was specifically amended in 1994 to manage incidental catch of pinnipeds and cetaceans in fishing gear (Baur *et al.* 1999). However, it is expected that continued expansion and industrialisation of fisheries at a global level, fuelled by an increase in human population, will lead to an increase in numbers of marine mammals incidentally captured in fishing gear (DeMaster *et al.* 2001).

While reporting marine mammal incidental catch may serve to indicate the existence of a problem, estimating the potential impact of these captures on specific marine mammal populations is much more difficult. It requires detailed knowledge of fishing effort, landed catches, and spatiotemporal distribution of both fishery and incidental catches, as well as population size, structure, and possible migratory behaviour of the marine mammal species in question. Such data have historically been difficult to obtain, and are still not available for many fisheries (Alverson *et al.* 1994; Clucas 1997). Read *et al.* (2003, 2006) estimated the total annual average number of marine mammals captured globally in fishing gear, based on data collected within the United States between 1990 and 1999. Their data indicated a mean annual bycatch estimate of 3,029 ± 316 cetaceans and 3,187 ± 341 pinnipeds caught annually in U.S. fisheries. When these results were extrapolated to global fisheries, they indicated that annual worldwide catch estimates might well reach several hundreds of thousands of animals, corroborating other studies (IWC 2002). Such catch rates raise serious concerns about the effects of fisheries on the survival of numerous marine mammal populations. In some populations of small cetaceans, incidental catch in fishing gear is believed to be the most important source of anthropogenic mortality, and it has the potential to drive some species with restricted distributions, such as the vaquita (*Phocoena sinus* Norris and McFarland), the baiji (*Lipotes vexillifer* Miller) and Hector's Dolphin (*Cephalorynchus hectori* Van Beneden) to extinction (Jefferson and Curry 1994; Silber *et al.* 1994; D'Agrosa *et al.* 2000; Dawson *et al.* 2001; Reeves *et al.* 2003).

1.3 - Mechanisms of Incidental Catch of Marine Mammals

For the most part, the capture of marine mammals in fishing gear is completely incidental to the capture of the target species. Historically, with the notable exception of the tuna purse-seine fleet operating in the eastern tropical Pacific Ocean, cetaceans and pinnipeds have not normally been targeted by commercial fishing operations, although recently developed artisanal fisheries in Peru, Chile, Sri Lanka and the Philippines are known to target small cetaceans for use as bait or human consumption (Crespo *et al.* 1994; Dolar 1994; IWC 1994; Lescrauwaet and Gibbons 1994; Reyes and Oporto 1994; Van Waerebeek *et al.* 1997; Reeves *et al.* 2003). Fishers in most other areas typically consider entanglements of marine mammals a nuisance, because of the time and effort required to extract the animals and the potential for damage done to the fishing gear (e.g. Lien 1980, 1994). Disentanglement of live marine mammals, and particularly large whales, may be dangerous to fishers if they are unfamiliar with the behaviour of the animals or otherwise not familiar with the safest procedures (Lien 1980, 1994).

In many jurisdictions, marine mammals are protected by some form of conservation legislation, which may or may not cover incidental mortality in fishing gear. However, enforcement of existing regulations is often difficult and always costly. In cases where incidentally-caught marine mammals are used for bait or human consumption, there appears to be an economic incentive to shift fishing activities towards directed catch of marine mammals regardless of legislation (Northridge and Hofman 1999; Reeves *et al.* 2003).

The vast majority of marine mammal incidental catches appears to occur in commercial gillnets (Northridge 1984, 1991; IWC 1994, 2000; Read 1994b; Read *et al.* 2003, 2006). These nets fish by entangling individual fishes by their gills or fins when they attempt to swim through them (hence their name). The mesh is typically made from materials such as nylon or monofilament polypropylene, which make the nets strong, light-weight and resistant to wear. Net fibre thickness ranges between 0.2-1 mm (FAO 1978; Fridman 1986; P. Walsh, MUN, pers. comm.). These nets are often designed to be near invisible under water in order to improve catches. Typically, they are deployed together in large numbers placed in line (termed a "fleet" or "string") near the sea floor. Nets are held more or less erect using a combination of floats on the headropes and lead rope, or "footrope" (Nédélec and Prado 1990; Fig. 1.1). "Bottom-set" gillnets target benthic species such as gadoids or flatfish. Alternatively, gillnets can be deployed close to the surface using larger floats, and target smaller pelagic species such as clupeids (Nédélec and Prado 1990).

Gillnets are considered to be a relatively selective type of fishing gear, allowing fish smaller than the net's mesh size to pass through freely, and minimizing entanglement of older, larger fish. For this reason, as well as the practical benefits described above, they are widespread in many fisheries around the world. However, the fact that modern net fibres are so strong and resistant to breaking increases the risk that air-breathing animals caught in them will have difficulty in disentangling themselves, and perhaps die of asphyxiation. Small cetaceans, pinnipeds, seaturtles and seabirds appear especially susceptible to incidental catch in these nets, primarily because their small body size prevents them from breaking out of the mesh if they get entangled (IWC 1994). Larger whales that get entangled in fishing gear may be unable to free themselves, or may attempt to leave the area, towing parts of the gear behind them. This will slow them down and may lead to subsequent mortality (e.g. Kraus, 1990; Lien 1994; Read 1994a; Volgenau *et al.* 1995; Knowlton and Kraus 2001; Baird *et al.*

2002). Responses of large whales to entanglement are variable and partially depend on the species involved (Lien 1994).

Most research on incidental catch of marine mammals to date has focused on cetaceans, with limited work being done on pinnipeds. Despite several decades of research, it remains unclear why these species are so susceptible to entanglement in bottom-set gillnets. Pinnipeds navigate underwater using a combination of visual cues and hydrodynamic reception by their vibrissae (Dehnhardt *et al.* 1998, 2001; Levenson and Schusterman 1999). Numerous species of odontocetes are known to possess a highly sophisticated bioacoustic sensory system that enables them to produce ultrasonic sounds and use the returning echoes to perceive the environment around them (Au 1993). This echolocation system enables them to forage and feed in dark or turbid waters where visual cues are limited or absent, detect conspecifics or predators, and alert them to potential obstacles in their path. Based on field observations and anatomical studies, it is assumed that all odontocetes have echolocation capabilities (e.g. Norris *et al.* 1961; Kastelein *et al.* 1995b; Wartzok and Ketten 1999). Experiments with captive odontocetes under controlled conditions, as well as with these animals in the wild, have shown that the acoustic capabilities of various species such as the harbour porpoise (*Phocoena phocoena* L.), Dall's porpoise (*Phocoenoides dalli* True) and bottlenose dolphin (*Tursiops truncatus* Montagu) should allow the animals to detect the net at sufficient distance to avoid entanglement (Au and Jones 1991; Au 1994; Hatakeyama *et al.* 1994; Kastelein *et al.* 2000). There are different theories about why small cetaceans still become entangled (IWC 1994; Lawson 2006):

1) Although small cetaceans have been shown to be able to detect nets in captive settings, their ability to detect returning echoes decreases markedly when the angle of approach to the net increases from 0° (i.e., away from a perpendicular approach). Gillnets have a density similar to seawater, and thus do not reflect strong echoes back to the animal (Kastelein *et al.* 2000). The knots in the mesh, together with the head- and footrope, provide the strongest echoes, but these may not be strong enough to alert an approaching cetacean to the presence of a barrier (Au 1994).

2) Small cetaceans may not echolocate continuously, for instance when attempting to avoid detection by predators or potential prey (Goodson *et al.* 1994; IWC 1994; Wilson and Dill 2002). Under these circumstances, nets can only be detected by means of passively listening to the sounds generated by movements of the net itself, or by visual observation. The sounds produced by water movement through a net or by wave action may be loud, but most of the emitted sound is low-frequency, to which small cetaceans are less sensitive (Lien *et al.* 1990). Wave action may produce areas of aerated water, especially in stormy weather, that may reduce the range and detection

capabilities of cetacean echolocation systems (IWC 1994). Vision is important to most species of cetaceans, but appears to be limited by attenuation at medium to long distances underwater. Most types of gillnets have been designed to appear nearly invisible under water, and it is possible that cetaceans are unable to visually detect nets in time to avoid collisions. However, observations of different species of cetaceans around nets indicate that they can visually detect these nets (Lien *et al.* 1990; Hatakeyama *et al.* 1994).

3) Upon successful acoustic detection, small cetaceans may not perceive gillnets as a physical barrier, due to lack of experience with such features in the marine environment (Au 1994; IWC 1994). It has been suggested that the low intensity of returning echoes may appear as a cloud of air bubbles or possibly aggregations of smaller animals as found in the deep scattering layer in pelagic ecosystems (Au 1994). Experiments on captive harbour porpoises indicate a potential for learning to avoid entanglement, provided the animal is capable of disentangling itself before dying (Kastelein *et al.* 1995a). This may explain the preponderance of (inexperienced) juveniles reported in some incidental catch studies (IWC 1994).

4) Small cetaceans may be foraging for food in the general location of the nets and focus all their attention on detecting prey, increasing their vulnerability to

entanglement. This is thought to play a role in the entanglement of harbour porpoise, which are known to engage in "bottom-grubbing" benthic foraging behaviour (Lockyer *et al.* 2001). It has been suggested that benthically foraging species such as the harbour porpoise are at greater risk of incidental catch because of this habit.

5) Some cetaceans may be attracted to nets by enhanced foraging opportunities due to entangled fish. Some species of cetaceans will engage in depredation, defined as the removal of, or damage to, captured fish or bait (Zollett and Read 2006). This behaviour is more commonly associated with pinnipeds (e.g. Lunneryd and Westerberg 1997; NMFS 1997), but has been reported in cetaceans, such as bottlenose dolphins (Lauriano *et al.* 2004). Small cetaceans may be unable to acoustically detect nets if many entangled fish are present, due to the much stronger echoes received from the fish (Au 1994). Interactions between marine mammals and mobile gear types such as trawls and longlines have also been reported (Corkeron *et al.* 1990; Pemberton *et al.* 1994; Wickens 1995; Yano and Dahlheim 1995; Visser 2000).

6) In some cases, cetaceans may be playing, resting, or sleeping, and thus fail to detect the net in time to avoid it. Cetaceans, unlike most other mammals, appear able to restrict brain activity to one brain hemisphere while the other

half is asleep, in order to always maintain the ability to surface and breathe (Rattenborg *et al.* 2000; Ridgway 2002). Several species of small cetaceans have been observed swimming with one hemisphere of their brain apparently asleep. However, it is not known whether odontocete echolocation is possible with unihemispheric brain activity (Rattenborg *et al.* 2000). In several oceanic dolphins, some animals in a pod appear to be actively echolocating at any given time, although the majority of their conspecifics may be resting, thereby increasing the chances of detection of obstacles (IWC 1994).

The specific cause of entanglement of small cetaceans is likely a combination of two or more of the factors listed above. Research is ongoing to determine the relative importance of these factors, and how to prevent incidental catches (e.g. Cox *et al.* 2003; Hood 2001; Kastelein *et al.* 1995a, 1995b, 2000; Lawson 2006; Lockyer 2001; Read 2000; Teilmann *et al.* 2006). These factors likely vary among different species, among different fisheries, and among different locations, contributing to the complex nature of this problem.

1.4 - History of Gillnet Fisheries in Newfoundland and Labrador

Incidental catches of marine mammals have been observed in a variety of commercial fisheries historically and currently active in Newfoundland and Labrador. They are primarily thought to be caused by the monofilament gillnets used in many sectors of these fisheries, and which has been implicated in the vast majority of incidental catches of marine mammals worldwide (Read 1994; Donovan and Bjørge 1995; Read *et al.* 2003). In this section, a concise overview of the history and current state of each fishery will be provided with a focus on technological advances in fishing equipment and the accompanying risks of incidental catch to marine mammals. From this point onward, all geographic designations refer to management units as defined by the Northwest Atlantic Fisheries Organization (NAFO), the organization responsible for international fisheries management in northwest Atlantic waters beyond the 200 nm limit of the Canadian Exclusive Economic Zone (EEZ; Figs. 1.2, 1.3, 1.4).

1.4.1 - The Nearshore and Offshore Atlantic Cod Fishery

The historical relevance of the fishery for Atlantic cod (*Gadus morhua* L.) for the development of Newfoundland and Labrador can hardly be overstated. From the 15^{th} century, the plentiful cod stocks in nearshore waters and on the Grand Banks attracted fishing fleets from France, England, Spain and Portugal, the major seafaring European nations of the time (Lear 1998; Fig.1.1). From this period onward, catches of cod remained the backbone of settlement and subsequent economic development of Newfoundland and Labrador until 1992.

The European fishery was initially seasonal in nature, undertaken by vessels crossing the Atlantic with most of their required equipment on board, with fish prepared on shore in temporary residences during the summer. By the mid-17th century, the first settlements had appeared, and by the 19th century, most nearshore and offshore waters, including the coastal waters of southern Labrador, were fished by native-born Newfoundlanders. It is estimated that between the late 16th and early 20th century, an annual average of between 100,000 and 300,000 mt of cod were caught by the combined nearshore and offshore fleets (DFO 1993a; Hutchings and Myers 1995). Most of these catches were processed by hand and exported as salted and dried cod. Despite significant fluctuations in catches, cod stocks remained so plentiful that Newfoundland became the world's largest exporter of salt fish by the middle of the 19th century (Ryan 1971).

During this time, the fishery was conducted primarily through use of baited hooks let down from the vessel, also known as "hook-and-line", or handline fishing, although longlines were introduced in the 19th century, and cast nets were used locally along the Northern Peninsula and the west coast (Hutchings and Myers 1995; Lear 1998). The first evidence of gillnet use in the Newfoundland fishery dates from the 1840s (Hutchings and Myers 1995). They enjoyed only limited popularity because the cotton fibres soaked up significant amounts of water while fishing, making them heavy and difficult to haul. The only fishery mainly conducted with gillnets was a herring fishery, which was used as bait for lobster traps (DFO 1993b). These nets would not become widely adopted by the Newfoundland fishing industry until the 1960s, by which time various technological advances in the development of monofilament gillnets made them a far more attractive gear type.

In contrast to the limited acceptance of the gillnet by Newfoundland fishers, the cod trap, invented in 1866 at Bonne Esperance, Quebec, rapidly became popular. This device, essentially a stationary seine net, works much like a herring weir, and consists of a lead net running from shore into deeper water, into a box-like arrangement of nets. Any fish travelling parallel to shore would follow the lead net into the trap where it would be retained. Cod traps have been implicated in incidental capture of small cetaceans and pinnipeds, but more commonly entangle various species of large whales, primarily humpback (*Megaptera novaeangliae* Borowski) and minke whales (*Balaenoptera acutorostrata* Lacépède; e.g. Lien 1980, 1983, 2001; Lien *et al.* 1989a).

In the first decades of the 20th century, several significant technological changes were taking place in the Newfoundland and Labrador cod fisheries. In 1906, the first steam-powered otter trawlers had appeared on the Grand Banks as part of the French fishing fleet, and by the 1930s, diesel-powered side-trawlers, where nets were hauled over the side of the vessel, were commonplace in Newfoundland waters. At this time, gasoline-powered engines first appeared in the nearshore fishery, although they would not become widespread until after

World War II. Additionally, innovations in hauling technology led to the development of hydraulic winches, which significantly increased the numbers of lines or gillnets that could be set (Hutchings and Myers 1995).

The development of large offshore freezer trawlers in the 1950s marked an even more important change, which significantly increased fisheries capacity. It encouraged the development of offshore fishing industries by countries other than those traditionally fishing in Newfoundland waters, such as the Soviet Union and its allied Eastern European states. At this point, a significant shift in fishing effort from the nearshore to offshore waters occurred (Templeman 1966). During the 1960s, the exploitation of fish stocks around the world increased significantly. Landed catches of cod reached record heights, with an estimate of over 800,000 mt of cod landed in 1968 (Templeman 1966; Hutchings and Myers 1995; Schiermeier, 2002). Most of these catches came from the offshore areas of the Grand Banks and Labrador and were caught by stern-hauled otter trawlers (known in Newfoundland as "draggers"), offshore longliners, and gillnetters, many of whom originated in Europe and Asia (Anonymous 2005d). Catches were further improved by the development of echo sounders and "fish finders", which enabled vessels to pinpoint the location of schools of fish with vastly improved accuracy.

Gillnets became significantly more popular among fishers in the 1960s. A significant innovation was the development of artificial fibres such as nylon and polypropylene. These materials were both lighter and significantly stronger than the cotton gillnets, and soon became the norm in the industry. During the 1960s, the federal government offered financial incentives for fishers to switch to gillnets under the Inshore Fisheries Assistance Programme (Wright 2001). There was a strong movement away from the traditional hook-and-line fishery in favour of the new and improved gillnets in most fishing communities of the province, except along the southwest coast of the island. The first gillnets used were multifilament nylon nets, but in later years the monofilament gillnets became more popular, chiefly because of a reduction in accidental tangling of the gear (Templeman 1966; Hutchings and Myers 1995). The effect of this change in technology on incidental catch of small cetaceans was, in all likelihood, highly significant, because nets made of these materials were significantly more difficult to detect underwater (both visually and acoustically by means of sonar), and too strong to be easily broken by a small marine mammal that inadvertently had become entangled (Read 1994).

During the 1970s cod populations contracted in many areas, particularly off the coast of Labrador (NAFO Divisions 2GH), causing a distinct southward shift in fishing effort (Fig. 1.3, 1.4). With fewer fish to catch, gear conflicts between trawlers and various other sectors became more common (Lear and

Parsons 1993). Cod and other groundfish stocks decreased dramatically during the mid-1970s, only to recover somewhat after the 200 nm Exclusive Economic Zone (EEZ) was declared by Canada in 1977 (Macdonald 1984). From this point onward, foreign fleets were no longer allowed to fish inside the Canadian EEZ, and they accordingly redirected their activities to international waters of the Grand Banks and Flemish Cap located just outside of this boundary (Fig. 1.2, 1.3, 1.4). They were replaced inside the 200 nm limit by a modern, Canadian-owned offshore trawler fleet which mainly operated out of Newfoundland ports (Macdonald 1984; Felt and Locke 1995; Schrank 1996).

During the 1980s, gillnet fisheries expanded further into offshore waters, a trend made possible by the continued development of accurate navigational equipment such as the land-based LORAN-C system. This technology enabled fishers to record the location of large fleets of fishing gear for future retrieval, greatly improving the usefulness of this gear type (Shortall 1973). During this time, there was a trend towards smaller mesh sizes, from approximately 18 cm (7") to the current 14 cm (5.5"; Hutchings and Myers 1995).

Catches of Atlantic cod remained stable at approximately 200,000 mt during the 1980s, but declined again in the early 1990s, primarily due to continued unsustainable fishing effort, despite initial conservation measures (Hutchings and Myers 1994; Sinclair and Murawski 1997). It is thought that various technological advantages enabled the fishing industry to maintain large catches despite dwindling stocks, particularly in offshore waters (Rose and Kulka 1999). Mangers' reliance on data from these increasingly efficient offshore fishing vessels meant that warning signals from researchers and other sectors of the industry were not heeded until it was too late (Anonymous 2005b). The declines were presumably exacerbated, and current recovery prevented, by concurrent changes in ambient average water temperature and shifts in the ecosystem, involving changes in the biomass of many species including (*Mallotus villosus* Müller) and harp seals (*Pagophilus groenlandicus* Erxleben) (e.g. DeYoung and Rose 1993; Colbourne *et al.* 1997; Drinkwater and Mountain 1997; Sinclair and Murawski 1997; Stenson *et al.* 1997a, 1997b; Rose and O'Driscoll 2002; Rose 2003).

In 1992, a moratorium was announced on the fishery for Northern cod in NAFO Divisions 2J3KL (Figs. 1.3, 1.4). A year later, this moratorium was extended to cover cod stocks off the south coast and in the Gulf of St. Lawrence (NAFO Divisions 3NO and 4R; DFO 2004d, 2004c; Figs. 1.3, 1.4). A Sentinel fishery was instituted in 1994, to enable fisheries scientists to obtain a minimum of fishery data even in areas otherwise closed to commercial fishing. Following strong pressure from the industry, a limited fishery was allowed on the cod stocks in nearshore areas of NAFO Subdivisions 3Ps, 3Pn and Divisions 4RS in 1997, using gillnets and longlines (Figs. 1.3, 1.4). Catches in these areas have remained at historically low levels (DFO 2004d, 2004c; Anonymous 2005d). In 1998, a small Index fishery was reopened for nearshore fishers along the northeast coast (NAFO Divisions 2J3KL; Anonymous 2005d; Fig. 1.4). In 2003, this fishery was again placed under moratorium due to continued lack of recovery (DFO 2004c; Anonymous 2005d; Fig. 1.4). In the same year, the fishery in the northern Gulf of St. Lawrence (NAFO Divisions 4RS and Subdivision 3Pn) was closed for similar reasons, but it reopened with a small quota in 2004 (Anonymous 2005d; Figs. 1.3, 1.4). In nearly 15 years since the declaration of the various moratoria, the offshore cod stocks have shown almost no signs of recovery, while the inshore stocks may have recovered to some extent in certain areas (Anonymous 2005d). However, there are distinct differences of opinion between fishers and management agencies regarding the present status of cod stocks and their ability to support a commercial fishery. The call to list several stocks of Atlantic cod under the federal Species At Risk Act (SARA) has exacerbated these differences of opinion (COSEWIC 2003). In April 2006, the federal government decided not to list Atlantic cod stocks off the east coast of Newfoundland, the northern Gulf of St. Lawrence and off Nova Scotia under the Species At Risk legislation, citing the development of "comprehensive recovery plans" for these stocks within the Department of Fisheries and Oceans (DFO 2006a). A small commercial directed fishery for cod along the northeast and west coasts of the island during the 2006 fishing season was announced soon after (DFO 2006b).

The nearshore fishery for cod has traditionally been the most widely practiced fishery in the province, and gillnets have been an important gear type for the majority of participants for many years. Most nearshore fishers were unable to use trawling gear due to the relatively large vessel size and engine requirements, and so gillnets, cod traps and longlines constituted the vast majority of fishing effort. Cod traps are not thought to pose a significant risk to small cetaceans, although large whales and basking sharks are known to have been entangled in cod traps since this gear type came into widespread use; its prevalence has dwindled considerably since the cod moratoria (J. Lien, MUN, pers. comm.). Longlines have been implicated in the incidental catch of large cetaceans as well as seabirds in Newfoundland and Labrador waters, but appear to impact small cetaceans to a far lesser extent (J. Lien, MUN, pers. comm.; Brothers *et al.* 1999; Ledwell 2005). However, it is probable that gillnet fisheries targeting Atlantic cod have regularly captured small cetaceans, as well as various species of seals, seabirds and other large marine vertebrates, since the widespread introduction of these nets in the 1960s (e.g. Lien 1983, 1989, 2001; Lien *et al.* 1989b; Piatt and Nettleship 1987; Piatt *et al.* 1984).

During this period, there have been significant fluctuations in overall fishing effort due to reductions in cod stocks. It is known that significant amounts of fishing gear, including gillnets, were used in the years immediately prior to the cod moratoria of the early 1990s, in an attempt to maintain catch rates despite decreasing stocks (J.Lien, MUN, pers.comm.). Such practices could easily have lead to an increase in catches of marine mammals. For instance, anecdotal reports and scientific studies indicate that large numbers of porpoises were being caught during the 1970s and 1980s (DFO 2001). It is therefore likely that the rate of increase of some marine mammal populations occurring in Newfoundland and Labrador waters was reduced to an unknown degree, and possibly to negative values, due to incidental mortality in cod gillnets. Current low fishing intensity is thought to have reduced the impact of gillnets on these populations, potentially allowing for some recovery.

1.4.2 - The Nearshore Lumpfish Fishery

The nearshore gillnet fishery for Lumpfish (*Cyclopterus lumpus* L.) in Newfoundland and Labrador waters is of comparatively recent origin. Although the fish is seasonally common in most nearshore areas of the province and had been used locally as a source of food and bait for lobster pots, it had historically never enjoyed widespread appeal as a target species among fishers (Collins 1976). In 1969, due to efforts by the provincial government to diversify the fishing industry, the first catches of lumpfish roe were landed for export to Germany, where they would be processed into substitute caviar. The fishery then went through a period of rapid expansion from a total landed catch of 21 mt in 1970 to over 3,000 mt in 1987. Newfoundland and Labrador quickly became one of the world's dominant exporters of lumpfish roe (Stevenson and Baird 1988), as closure of fisheries for Atlantic cod and other groundfish in the early 1990s led to a significant increase in the number of fishers targeting this species. There have been several significant fluctuations in landed catches since then, with extremely low catches being reported in recent years (less than 500 mt; Myers and Sjare 1995; DFO 2004b). The overall catch per unit effort appears to also have dropped significantly (Myers and Sjare 1995; Neis *et al.* 1999).

Lumpfish are captured by using large-mesh (22 cm/10.5") monofilament gillnets, primarily from small vessels in nearshore waters, during a relatively short fishing season from late April to early June, when the fish migrate inshore to spawn. The fishery is practiced in all areas of the province, but especially along the south coast of the island (DFO 2002a). Nets are often left in the water for several days; the resilient nature of lumpfish enables them to survive entanglement in this gear for this long (J. Lawson, DFO-NL, pers. comm.). Since the roe (eggs) of the lumpfish is generally considered to be the only marketable product, males and juvenile females, as well as the carcasses of the mature females, are usually discarded. Concerns have been raised over the species' vulnerability to overexploitation as a result of exclusively targeting mature pre-spawning females, who are capable of producing approximately 1 kg of roe (~140,000 eggs; Scott and Scott 1988; DFO 2004b).

Despite the rapid increase in numbers of fishers targeting lumpfish since the closure of the cod fisheries in the 1990s, and considerable catches of pinnipeds, the risk of entanglement of small cetaceans in lumpfish gear is thought to be limited (Walsh *et al.* 2000). This is due to the early opening and closing of the fishing season, when many small cetaceans are thought to still be in warmer waters further south and/or offshore. However, small cetaceans have been reported as incidental catch in this fishery (Walsh *et al.* 2000), suggesting that this risk evaluation may need to be reviewed in the light of a detailed analysis of incidental catch dates.

1.4.3 - The Nearshore Atlantic Herring Fishery

The nearshore fishery for Atlantic herring (*Clupea harengus harengus* L.), while not as socio-economically significant as the cod fishery, has existed in the province for centuries, both as an independent commercial fishery and a bait fishery to support the cod hook and line fishing effort. The main centres of herring abundance are the nearshore waters off the south and west coasts, particularly in Fortune Bay and Placentia Bay along the south coast (NAFO units 3Psbc), and waters around the Port-au-Port Peninsula on the southwest coast (4Rcd; Fig. 1.4). Atlantic herring approach the northernmost edge of their range along the northeast coast of Newfoundland and Labrador, and their distribution in this area is therefore susceptible to changing environmental circumstances (DFO 2004a). Most large bays have resident stocks of herring, which can each be divided into spring and fall spawners. These two groups do not appear to interbreed, and are considered separate substocks for management purposes (Scott and Scott 1988; DFO 1993b).

The fishery in its most traditional form uses small-mesh (~6 cm/2.25") monofilament pelagic gillnets. These nets are generally set in shallow nearshore waters, and are tended daily to ensure quality. The use of purse seines became more common in the late 1960s, and these nets currently account for approximately half of the total annual catch. Bar seines are also used in some areas such as Fortune Bay in preference to purse seines (DFO 1993b, 2004a, 2004f). Most landings are exported, although an unmonitored fishery exists for bait in pots set for lobster (*Homarus americanus* Milne Edwards) and snow crab (DFO 1993b, 2004a, 2004f). This bait fishery typically does not involve more than 1 net per license holder.

Herring stocks were heavily fished for producing fishmeal in the 1960s, and stocks have not fully recovered from this overexploitation (Rose, 2003). Most of the current fishery for Atlantic herring in Newfoundland waters occurs in nearshore waters along the west coast of the island (NAFO Division 4R; DFO 2004f; Fig. 1.3). The main fishing season typically occurs during the spawning period of the fall substocks, although historically this has been known to fluctuate (DFO 2004a). Annual landings have averaged approximately 15,000 mt in this area over the last 15 years, with most of these catches taken by large seining vessels in NAFO area 4Rd (Fig. 1.4). Most gillnets are used in NAFO unit 4Ra (Strait of Belle Isle; Figs. 1.2, 1.4), where catches of small cetaceans, particularly harbour porpoises, have also been reported anecdotally. The herring gillnet fishery along the northeast and south coasts is typically restricted to early spring, and catches are typically limited (DFO 2004a, 2004f).

Impacts of herring purse seine fisheries in the northwest Atlantic on marine mammals appear to be negligible, with only occasional reports of incidental captures that could often be released alive (Anonymous 2005e; Baraff and Loughlin 2000; Gilbert and Wynne 1985; NEFMC 2004). Based on anecdotal information, purse seines also have never been implicated in incidental catch of small cetaceans in Newfoundland and Labrador (J.Lien, MUN, pers. comm.). It is possible that the increased use of purse seines to catch herring may have reduced the use of gillnets, thereby potentially reducing incidental catch of marine mammals.

1.4.4 - The Offshore Monkfish and Skate Fishery

The directed offshore fishery for Monkfish (*Lophius americanus* Valenciennes) and skates (various *Rajidae* species, but principally thorny skate *Amblyraja radiata* Donovan) is also a relatively recent phenomenon in Newfoundland and Labrador waters. Monkfish and skates had been caught as bycatch species in Atlantic cod and other groundfish fisheries for many years. However, it was not until the implementation of the various groundfish moratoria in the first half of the 1990s that a directed, mixed fishery for monkfish and skates developed in this province. The vast majority of fishing activity targeting these species takes place on the south-western slope of the Grand Banks and the northern edge of the Laurentian Channel (NAFO Division 3LNOP), with most catches occurring in NAFO units 3Oa, 3Oc and 3Oe (Kulka and Miri 2001; Figs. 1.2, 1.4). Catches for monkfish generally remained low in terms of total weight landed (on the order of 300 mt) during the 1990s, but increased significantly in the years immediately after the turn of the century (to 2,795 mt in 2003; DFO 2003). This increase was driven by an increase in fishing effort in response to favourable market conditions. Catches of skates appear to have remained stable during this time, with a far lower average annual landed catch of approximately 1,350 mt (DFO 2004b).

This fishery was originally set up using trawl gear. However, an experimental bottom-set monofilament gillnet fishery in 1993 proved successful, and became the standard for this fishery up to this day (Kulka and Miri 2001). Nets used in this fishery have a large mesh size (~30 cm/12"), and are typically set in a relatively narrow area along the continental shelf break of the south-western Grand Banks and the Laurentian channel, at a depth of several hundred meters. One noteworthy aspect of this fishery is the tendency for the net to be deployed in such a way that a significant part of the net "overhangs" the sea floor, rather than stands up straight in the water column. This deployment strategy ensures higher catches of monkfish and skates, by also entangling fish when they rise off the sea floor while foraging and travelling. Nets are typically left to soak for several days, principally because of the significant time involved in travelling to and from these fishing grounds.

The gillnet fishery for monkfish and skates has the potential to capture small cetaceans and pinnipeds (Perez and Wahrlich 2005). The fishery is prosecuted during the summer months in regions of comparatively high productivity, which also attract small cetaceans. Based on the recent increase in numbers of fishers participating in this fishery, the potential risk of entanglement to marine mammals is thought to also have increased. However, it is not known to what extent the fishery overlaps with areas of importance to marine mammals.

1.4.5 - The Offshore White Hake Fishery

White hake (*Urophycis tenuis* Mitchill) is a benthic gadoid species commonly found in waters of 200 m and deeper off the continental shelf and slope. It has been reported from southern Labrador southward to North Carolina, but in Canadian waters is most common in the southern Gulf of St. Lawrence, the continental shelf of Nova Scotia and the southern Grand Banks of Newfoundland (Scott and Scott 1988; DFO, 2002). A preference for water temperatures of 5-

11°C normally restricts the distribution of this species in Newfoundland waters to a comparatively narrow band of shelf and slope waters off the southwestern Grand Banks and the Laurentian Channel (DFO, 2002; Fig. 1.2).

White hake has never supported a fishery of great economic significance in this region. The fishery started in the early 1970s, using a combination of gillnets (13.3 cm/5.25" mesh size) and trawls (Scott and Scott 1988). Between 1977 and 1990, average annual landings were approximately 5,000 mt, the majority of which was landed by Canadian vessels, although foreign vessels also targeted this species (DFO 2002b). From 1988 to 1995, colder seawater temperatures are believed to have caused a significant reduction in abundance of white hake in the area. In recent years, overall landings have not exceeded 1,200 mt, although this reduction was at least partially caused by fisheries closures due to high amounts of cod bycatch (DFO 2002b). Current gillnet fisheries account for 300-350 mt in annual landings, or approximately a quarter of total effort.

The gillnet fishery is limited geographically, with most effort concentrated offshore in the 3O-3Ps border area along the continental shelf break (Fig. 1.4), where it has been closely associated with the fishery for monkfish and skates that takes place in the same region. The nearshore component of this fishery is limited but has increased in recent years, with most catches originating in NAFO unit 3Psa (Fig. 1.4).

The risks for entanglement of marine mammals in the white hake fishery appear to be comparable to the fisheries for monkfish and skates, in terms of the seasonality and geographical distribution of the offshore fishery along the edge of the Grand Banks. However, nets targeting white hake are deployed in the manner typical for gillnets, more or less perpendicular towards the seabed, and thus would not normally present much of an overhang to capture marine mammals. Some incidental catches of marine mammals in these gillnets may occur, but overall the white hake fishery probably constitutes a minor risk for marine mammals in Newfoundland and Labrador.

1.4.6 - The Nearshore and Offshore Greenland Halibut Fisheries

Greenland halibut (*Reinhardtius hippoglossoides* Walbaum), commonly known in Newfoundland and Labrador as "turbot", is a deepwater fish occurring offshore along the edge and slope of the continental shelf, as well as in deep sections of nearshore bays and channels, throughout most of the waters of the province. It has been reported from the high Arctic southward to the Scotian Shelf, and is most commonly encountered between 500-1,200 m (Vis *et al.* 1997). Greenland halibut appear to form a single stock throughout Atlantic Canadian waters, with spawning grounds in the Davis Strait area, with the exception of a small subpopulation in the Gulf of St. Lawrence (Scott and Scott 1988; Vis *et al.* 1997). The deepwater habits of this species have made it difficult to capture in commercially attractive quantities until the 1990s. A small-scale hook-and-line fishery for this species was active in some areas of Newfoundland and Labrador, but it was not of major economic significance (Scott and Scott 1988). Due to the collapse of stocks of Atlantic cod and other species in the early 1990s, the fishery for Greenland halibut has become the major demersal fishery in the northwest Atlantic, especially in the Davis Strait area (NAFO Subarea 0; Anonymous 2005a; Fig. 1.3). Catches of Greenland halibut increased from approximately 500 mt in 1960 to over 40,000 mt in 1979, but have witnessed subsequent steep declines in some areas, with current total annual landings averaging at approximately 13,000 mt (Templeman1966; Anonymous 2005a). In offshore waters, the fishery is conducted from large vessels by means of bottom trawls, longlines and gillnets (mesh size ~15 cm/6"), whereas the nearshore fishery typically uses gillnets of similar mesh size deployed from smaller vessels.

The nearshore component of the fishery for this species is somewhat limited, with current fisheries concentrated in deep waters in Fortune Bay (NAFO unit 3Psb), as well as locally off the northeast coast (NAFO Divisions 3KL) and off the west coast (primarily NAFO units 4Rbc; Figs. 1.3, 1.4). The offshore component typically targets fish along the shelf edge from the southern Grand

Banks north to Labrador, particularly along an area north of the Grand Banks known as the Orphan Basin (NAFO units 3Kg3Lde; Fig. 1.4). In addition, there is significant fishing activity in waters around Baffin Island (NAFO Subarea 0Fig. ; Figs. Fig. 1.3), including the recent development of small-scale winter fisheries using longlines through the ice (Walsh 2006).

The main threats towards marine mammals in this fishery appear to come from the gillnetting sector. In recent years, there has been a decrease in the amount of fish landed using gillnets, as fishing effort has shifted towards bottom trawls and longlines. This has been especially pronounced in offshore waters (in NAFO Subarea 0, NAFO Divisions 2GHJ, 3K, 3L and 3N; Fig. 1.3). However, in 2006 many fishers in waters off northern Labrador and Baffin Island (NAFO Subarea 0) switched back to using gillnets after suffering continued and repeated depredation of bait and hooked Greenland halibut by killer whales (*Orcinus orca* L.), sperm whales (*Physeter macrocephalus* L.) and northern bottlenosed whales (*Hyperoodon ampullatus* Forster) (Ledwell 2005; J. Lawson, DFO-NL, pers. comm.). These events may have been instigated by animals being fed fish offal associated with this and other fisheries. At this point, the scope of this interaction and its potential impact remain to be investigated, but in recent years there have been anecdotal reports of entanglement and mortalities of several whale species (Ledwell 2005; J. Lawson, DFO-NL, pers. comm.). In summary, while the overall risk of entanglement in gillnets used in the Greenland halibut fishery is thought to have declined for marine mammals in Newfoundland and Labrador waters, locally gillnets are (again) the fishing gear of choice (P. Winger, MI-MUN, pers. comm.).

1.4.7 - The Nearshore and Offshore Redfish Fishery

Redfish (*Sebastes* spp.) occur in cold waters from Baffin Island south to waters off New Jersey, and are principally found at depths between 100-1,000 m (Scott and Scott 1988; Anonymous 1991). Three closely related species (*S. fasciatus* Storer, *S. marinus* L., and *S. mentella* Travin) occur in this area, but are difficult to distinguish without specialist knowledge. For commercial fisheries purposes, all species are managed as one unit. It is thought that *S. mentella* constitutes the majority of commercial catches in Atlantic Canadian waters (DFO 2004e).

These species were not commercially exploited in any significant way until recently, when technological developments and associated expansion of fishing effort in the 1950s brought the stocks within the reach of industrial fishing (Anonymous 1991). Catches peaked at 400,000 mt in 1959 and have since declined to below 200,000 mt for the entire northwest Atlantic (Lear 1998), with current catches in Newfoundland and Labrador waters concentrated along the southwestern corner of the island of Newfoundland (NAFO Divisions 3O, Subdivisions 3Ps and 3Pn, and the southern portion of Division 4R; Figs. 1.3). In this area, catches have remained below 10,000 mt in recent years (DFO 2004e). The current fishery employs a combination of deepwater bottom trawls, midwater trawls and bottom-set gillnets (~14 cm/5.5" mesh size). The gillnet component of the fishery is almost exclusively located in nearshore waters in NAFO Subdivisions 3Ps and 3Pn (Figs. 1.3, 1.4).

Overall, the risk of entanglement of small cetaceans in this fishery appears to be limited, due to its geographically localized nature along the southern edge of the Grand Banks and in the Cabot Strait area (NAFO Divisions 3Pn, 3Ps and 4Vn). Gillnets account for <10% of total annual redfish landings in Newfoundland waters, but generate between 45-60% of annual landings in nearshore waters along the south coast. Nets are similar to other deepwater fisheries that have been known to catch marine mammals and incidental catches of marine mammals in redfish gillnets in these areas are therefore possible (Perez and Wahrlich 2005). Gillnet redfish catches have remained relatively stable in recent years, and therefore no changes in risk to marine mammals are expected.

1.4.8 - The Nearshore Winter Flounder Fishery

Winter flounder (*Pseudopleuronectes americanus* Walbaum) is a species of flatfish that occurs commonly in nearshore waters from southern Labrador to Georgia (Scott and Scott 1988). The species is locally known as "blackback flounder." It has historically not been of great commercial significance in

Newfoundland and Labrador, although some fishers used it as baitfish for lobster traps. The directed fishery is commonly conducted in nearshore waters with gillnets (mesh size variable between approximately 16.5 cm-20.5 cm/6.5"-8"), as well as various seines and bottom trawls. Catches have fluctuated in recent years, varying between 500-1,500 mt (DFO 1999). The main purpose of this fishery continues to be to supply bait for the lobster and crab fisheries.

It is presently unknown to what extent gillnets targeting winter flounder pose a risk to marine mammals in Newfoundland and Labrador. Many fishers who use this species as bait in lobster traps set their nets in very shallow water (<10 m), which are likely to be less frequented by small cetaceans, but may be frequented by pinnipeds. However, it has been suggested that, for many fishers who participate in this fishery, the target species is actually the limited amounts of Atlantic cod that are allowed as incidental catch, in contravention of the cod moratoria (DFO 2004g; J. Lien, pers. comm. 2005; Anonymous 2005c). Such a fishery would in all likelihood be prosecuted in deeper waters where cod are more abundant, and thus pose a greater risk of incidentally catching small cetaceans. Greater interest in this fishery could increase the number of gillnets used in these areas, and potentially contribute to greater amounts of incidental catch of marine mammals.

1.4.9 - Summary of Entanglement Risks for Small Cetaceans in Newfoundland and Labrador Waters

Despite significant reductions in fishing effort since the cod moratoria were imposed in 1992, the nearshore Atlantic cod fishery appears to present the greatest risk in absolute terms for small cetaceans in nearshore waters, due to its widespread nature and the significant numbers of gillnets used. The lumpfish fishery is also extensive in nature and uses large numbers of gillnets. However, early opening and closing of the fishing season may limit the degree of interaction with marine mammals, particularly small cetaceans. The nearshore fishery for Atlantic herring is limited geographically and may therefore only be of limited overall importance to marine mammals in this province. The offshore fisheries for monkfish, skates, white hake and Greenland halibut along the edge of the Grand Banks may be of potential significance due to their presence in highly productive waters that may attract marine mammals. The fishery for redfish is thought to be of minimal importance due to its limited geographic scale. Finally, the winter flounder fishery is thought to be of little importance due to its concentration in very shallow waters; however, an expansion of this fishery into deeper waters is a potential cause for concern. None of these fisheries, with the exception of the fishery for Atlantic cod, has ever been evaluated for incidental catch of small cetaceans (Lien 1989, 2001; Lien *et al.* 1989b; Piatt and Nettleship 1987).

1.5 - Biology and Status of Small Odontocetes in Newfoundland and Labrador Waters

The harbour porpoise is a small cetacean species that is frequently captured in gillnets in Newfoundland and Labrador waters (Lien *et al.* 1989, 2001; Lawson *et al.* 2004; Piatt and Nettleship 1987). A sizeable quantity of research has been done on this species in various parts of its range, but many aspects of its biology and stock status in Newfoundland and Labrador waters remain unknown. In addition to the harbour porpoise, other commonly occurring species of small odontocetes in these waters are pelagic dolphins, most notably the common dolphin (*Delphinus delphis* L.), the Atlantic white-sided dolphin (*Lagenorhynchus acutus* Gray) and the white-beaked dolphin (*L. albirostris* Gray). Despite their regular occurrence in the northwest Atlantic, little is known about their biology and stock status in this area.

1.5.1 - Harbour Porpoise Biology and Stock Status

The harbour porpoise is the smallest of all odontocetes inhabiting Atlantic Canadian waters, with lengths and weights ranging between approximately 145 cm and 50 kg for males and 160 cm and 65 kg for females (Richardson 1992; Carwardine 1995; Read and Tolley 1997; Read 1999; Lockyer and Kinze 2003). The species has been reported in all areas off Newfoundland and Labrador, but is most commonly observed in nearshore waters (Lien 1985, 1989; Alling and

Whitehead 1987; Stenson and Reddin 1997; Stenson 2003). It is known locally as the 'puffin pig', for the sound produced during exhalation (Ledwell 2005).

Harbour porpoises are not long-lived; most die before reaching 10 years, although specimens of up to 24 years have been reported (Richardson 1992; Lockyer 1995; Read and Hohn 1995). Mean ages at sexual maturity are 3 – 4 years for females, and 2 – 3 years for males (Read 1990; Read and Gaskin 1990; Richardson 1992). Reproduction is strongly seasonal, with both ovulation and peak sperm production occurring in June-July in most areas (Neimanis *et al.* 2000). Gestation lasts for approximately 11 months, and calves are born between mid-May and mid-July; they remain with their mothers for a subsequent lactation period of approximately 8 months (Börjesson and Read 2003; Lockyer 2003). Studies in Denmark and Germany indicate a concentration of mother-calf pairs in shallow nearshore waters, suggesting that these areas are important for reproduction (Sonntag *et al.* 1999; Lockyer and Kinze 2003).

Harbour porpoises are typically observed alone, in pairs or in small groups, though larger aggregations of up to several hundred have occasionally been reported in areas where exceptional feeding opportunities exist, or where narrow straits constrict migration patterns (Carwardine 1995; Kinze 1995). As a rule, harbour porpoises do not approach boats, and are unobtrusive at the surface. This, together with its small size, makes the harbour porpoise difficult to detect visually, complicating abundance estimations (Palka 1995).

Harbour porpoise have been reported to feed on a variety of pelagic and benthic fish species, as well as various invertebrates (Recchia and Read 1989; Smith and Read 1992; Fontaine *et al.* 1994; Aarefjord *et al.* 1995; Gannon *et al.* 1998; Börjesson *et al.* 2003; Lockyer and Kinze 2003; Víkingsson *et al.* 2003). Because of low sampling effort, the seasonal variability of the diet is not well documented (Palka *et al.* 1996). Animals usually forage alone or in small groups, although larger groups have been observed feeding communally in some areas (Pierpoint *et al.* 1994). Harbour porpoise have been observed in multi-species feeding associations (Camphuysen and Webb 1999). Many of the prey items of harbour porpoise are also sought out by commercially targeted fish species, which may lead porpoises into waters where fishing occurs. In some cases (e.g. when fishing for species such as Atlantic herring), fisheries directly target an important harbour porpoise prey species, which may lead to harbour porpoises encountering fishing gear.

Observations on captive harbour porpoises have shown them to engage in "bottom-grubbing" behaviour in which the animals position themselves facing downward directly towards the sediment and proceed to excavate prey items that may be hidden among debris or buried under the sand while slowly rotating around their body axis by movements of the tail flukes (Lockyer *et al.* 2001; personal observation). Harbour porpoises are able to detect objects buried several centimetres deep in sediment using echolocation, and are assumed to hunt benthic fish in this fashion (Kastelein *et al.* 1997). A similar behaviour, termed "crater feeding", has been observed under natural conditions in various populations of bottlenose dolphins (Rossbach and Herzing 1997, 1999; Connor *et al.* 2000). During studies of this behaviour on captive animals the porpoises displayed reduced vigilance toward the impending threat of incidental capture in fishing gear (Lockyer *et al.* 2001; IWC 2002).

Harbour porpoises may spend days, even weeks in relatively restricted areas, then quickly move large distances to spend time in other, fairly restricted areas (Read and Westgate 1997). In the Gulf of Maine/Bay of Fundy region, harbour porpoises that were equipped with satellite tags routinely travelled distances of between 10 - 30 km in a day, implying large seasonal home ranges (Read and Westgate 1997). There is some evidence that individuals may return to the same areas for several consecutive years (Gaskin and Watson 1985). Small-scale oceanographic features, such as temporary fronts and eddies off islands and headlands, may be important in determining distribution of harbour porpoises (Johnston and Westgate 2005).

Harbour porpoises have traditionally been considered to be limited to relatively nearshore waters of depths less than ~200 m (Read, 1999). Harbour porpoises are commonly reported in shallow inshore waters, but they have also been observed or incidentally captured in deep offshore waters (Christensen and Lear 1977; Bjørge and Øien 1995; Northridge *et al.* 1995; Read and Westgate 1997; Stenson and Reddin 1997). A dive depth of 226 m was recorded for a harbour porpoise in the Bay of Fundy (Westgate *et al.* 1995). However, average reported dive depths are typically around 20 to 50 m (Westgate *et al.* 1995; Otani *et al.* 1998).

Harbour porpoises occur in three populations in the northern hemisphere (Read 1999). In the western north Atlantic, harbour porpoises (*P. p. phocoena*) are found from Baffin Island and western Greenland southward to at least Cape Hatteras, North Carolina. In the eastern north Atlantic, animals range from the Barents and White Seas southward to at least Moroccan waters, and into the Baltic Sea (Gaskin 1984; IWC 1996; Koschinsky 2002). There is a separate harbour porpoise population (*P. p. relicta*) in the Black Sea and Sea of Azov (Tomilin 1957; Read 1999). Finally, harbour porpoises (*P. p. vomerina*) occur on both sides of the northern Pacific Ocean, ranging as far north as the Beaufort Sea and the Mackenzie River delta (Northwest Territories, Canada) and as far south as Japan and California (Barlow and Hanan 1995; van Bree *et al.* 1977; Gaskin 1984, 1992c; Read 1999).

The population structure of harbour porpoises within the northwest Atlantic region has not yet been completely elucidated. Harbour porpoises occur regularly in the Gulf of Maine and Bay of Fundy, throughout the Gulf of St. Lawrence, around Newfoundland and Labrador, and off southwestern Greenland north to at least Upernavik (Palka *et al.* 1996; Read 1999). These four general areas were originally defined as subpopulations by Gaskin (1984, 1992c) and were later adopted as management units by the International Whaling Commission (IWC 1996). Recent studies using skull morphometrics, genetics and contaminant analyses have broadly confirmed this description of harbour porpoise subpopulation structure in Atlantic Canada (Gao and Gaskin 1996; Wang *et al.* 1996; Rosel *et al.* 1999a; Westgate and Tolley 1999). However, many details of the relationships between these subpopulations are still unclear. Female harbour porpoises appear to show a greater degree of philopatry, and are therefore more likely to be identifiable to a subpopulation level, than males (Tiedemann *et al.* 1996; Wang *et al.* 1996; Borjesson and Berggren 1997; Walton 1997; Rosel *et al.* 1999a; Andersen *et al.* 2001). Lack of variability on a microsatellite level among harbour porpoises from the four putative populations might be explained by male-mediated gene flow (Wang *et al.* 1996; Rosel *et al.* 1999a). Small-scale population differentiation has been established within a continuous distribution in various areas, based on both nuclear and mitochondrial DNA (Rosel *et al.* 1999a; Chivers *et al.* 2002). Variability in migration patterns between males and females has also been suggested for some populations (Andersen *et al.* 2001).

Most observations of harbour porpoises in the waters of Newfoundland and Labrador occur during the summer months. The species appears to only be seasonally present in most of Atlantic Canada (Gaskin 1984, 1992c; Palka *et al.* 1996; Read and Westgate 1997; Westgate and Tolley 1999). Aerial and ship-based surveys indicate an abundance of approximately 89,700 harbour porpoises in the Gulf of Maine/Bay of Fundy region, and between 12,000-21,000 animals in the Gulf of St. Lawrence (latter estimate uncorrected for visibility biases such as submerged animals; Kingsley and Reeves 1996; Palka 2000; COSEWIC 2003). No abundance estimates are currently available for Newfoundland and Labrador or Greenland waters. Also, their winter distribution in the northwest Atlantic region is not well understood. During winter, low seawater temperatures and sea ice formation occur throughout large portions of the region. It is thought that most harbour porpoises leave nearshore Atlantic Canadian waters in the fall to avoid lack of food and possible ice entrapment (Worthy and Edwards 1990; Gaskin 1992c; Brodie 1995; McLellan *et al.* 2002; Stenson 2003). Seasonal movements of harbour porpoise have been identified elsewhere in the species' range (Kinze 1995; Northridge *et al.* 1995; Read and Westgate 1997). Stranding reports of harbour porpoises in the mid-Atlantic United States increase significantly during late winter and early spring, suggesting some form of seasonal north-south migration along the coast, or offshore along the continental shelf (Polachek *et al.* 1995; Read and Westgate 1997; Rosel *et al.* 1999a; Rossman and Merrick 1999). Mitochondrial DNA analysis of these stranded animals indicates that animals from all four northwest Atlantic subpopulations are present in waters off the mid-Atlantic United States during winter (Rosel *et al* 1999a). However, little else is known about these movements at present.

1.5.2 - Common Dolphin Biology and Stock Status

Common dolphins are among the smallest delphinids inhabiting Newfoundland and Labrador waters, with adults reaching up to 2.6 m in length and weighing up to 135 kg (Evans 1994). Common dolphins are generally pelagic in distribution, but occasionally individuals or small groups come inshore (Gaskin 1992b). In the northwestern Atlantic, the species appears to be closely associated with the continental shelf edge, occurring in waters from 200-2000 m (Waring *et al.* 2003). Common dolphins are seldom encountered alone, and most commonly occur in groups of 10-200 animals, although much larger aggregations have been reported (Gaskin 1992b; Evans 1994). The species has been reported mainly in offshore waters to the south and southeast of Newfoundland (Whitehead and Glass 1985). It is locally known as the "saddleback dolphin", for its distinctive dark cape, easily spotted when the animal bowrides.

The diet of common dolphins is primarily composed of small pelagic schooling fish and cephalopods (Overholtz and Waring 1991; Couperus 1997; Ohizumi *et al.* 1998). Common dolphins often hunt cooperatively, and the species is well known for its role in multispecies feeding aggregations in various areas around the world (Clua and Grosvalet 2001). Little work has been done on quantifying the dive capabilities of common dolphins. Stomach content records indicate that animals dive down to forage in the deep scattering layer, which will rise up to within a few hundred meters below the surface at night (Scott and Scott 1988; Couperus 1997). However, no direct measurements are available.

Worldwide, common dolphins have been reported caught in various types of fishing gear, particularly pelagic trawls and gillnets (Bjørge *et al.* 1994; Couperus 1997; Tregenza *et al.* 1997; Tregenza and Collet 1998; Morizur *et al.* 1999; Reeves *et al.* 2003; Carretta *et al.* 2004). Dolphins may forage around or inside the trawls, which often concentrate prey (Tregenza and Collet 1998; Morizur *et al.* 1999). It is thought that incidental catch in trawls occurs when the trawl collapses if the vessel suddenly slows down or changes direction. Dolphins may also be attracted to sounds of gillnets being set and hauled, as well as to bright lights when fishing at night, potentially leading to entanglement (Tregenza *et al.* 1997). One such record is available from Spanish trawlers off the Grand Banks (Lens 1997).

Common dolphins are considered seasonal visitors to Canadian waters (Gaskin 1992b). Concentrations of common dolphins have been reported on the offshore banks and shelf edge off Nova Scotia and southern Newfoundland, including the Flemish Cap, during summer and fall (Sergeant *et al.* 1970; Gowans and Whitehead 1995; Waring *et al.* 2003). In these waters, the species appears to be associated with the warm waters of the Gulf Stream and north Atlantic Current. Sightings of common dolphins off the eastern coast of the United States were reduced during the summer months during the 1978-1982 CeTAP surveys, suggesting seasonal northward movement of the stock towards Atlantic Canada, including waters off southern Newfoundland (CeTAP 1982).

The taxonomical status of common dolphins has proven to be complex. Based on morphological, behavioural and genetic evidence, two species are currently recognised: the short-beaked common dolphin (*D. delphis*) and the long-beaked common dolphin (*D. capensis*) (Evans 1994; Heyning and Perrin 1994; Rosel *et al.* 1994; Rice 1998; Jefferson and Van Waerebeek 2002). Common dolphins in Atlantic Canadian and northeastern United States waters are considered to be the short-beaked species (Perrin 2002; Waring *et al.* 2003).

The best current population estimate for common dolphins in northeast U.S. waters adjacent to Canadian waters is on the order of 90,000 animals during late spring/early summer (Palka 2006). There is no information on stock structure in the region at present, nor is there any detailed information on migration routes and calving grounds. Studies on common dolphin stock structure within the northwestern Atlantic are currently ongoing; variability in morphometrics suggests the existence of more than one stock (Waring *et al.* 2003).

1.5.3 - Atlantic White-Sided Dolphin Biology and Stock Status

The Atlantic white-sided dolphin is endemic to the north Atlantic. It is a stockily built dolphin, with adult males measuring up to 270 cm and weighing up to 230 kg; adult females are slightly smaller (Reeves *et al.* 1999a). The species is most commonly encountered in waters over the continental shelf and slope of between 200 and 1,000 m depth, but also occurs close to shore. It is a social animal, almost always observed in pods of 5 to 50 individuals, although much larger pods have been reported in some areas (Evans 1980). They are highly active at the surface, and are often attracted to vessels. The species has been recorded in most Newfoundland and Labrador waters, at least as far north as shelf waters off southern Labrador (Sergeant *et al.* 1980; Stenson and Reddin 1997; Reeves *et al.* 1999a).

Atlantic white-sided dolphins are catholic feeders, preying on a variety of epipelagic and mesopelagic species of fish such as herring, mackerel, gadoids, and sand lance, as well as squid (Selzer and Payne 1988; Gaskin 1992a; Couperus 1997; Rogan *et al.* 1997). They often hunt cooperatively, and the species has been reported as part of multispecies feeding aggregations in various parts of its range (De Boer 1989). In parts of Newfoundland and Labrador, these animals are called "squidhounds", ostensibly because of the greater emphasis on squids in their diet, or "jumpers" because of their lively behaviour at the surface. There is only limited information on the dive capacity of Atlantic white-sided dolphins. A single individual was equipped with a satellite tag in the Gulf of Maine in 1991; it remained in the area for at least 6 days, during which the animal stuck closely to the region around the 100 m isobath (Mate *et al.* 1994). No dive depth data were available, but the vast majority of dives were less than 1 minute in duration. This reinforces the conclusion that the Atlantic white-sided dolphin is a fast-swimming forager on pelagic prey species. Atlantic white-sided dolphins have been reported caught in various types of fishing gear, particularly trawls and gillnets (Bjørge *et al.* 1994; Couperus 1997; Morizur *et al.* 1999). Dolphins may forage around or inside the trawls, and become trapped when the trawl collapses if the vessel suddenly slows down or changes direction (Tregenza and Collet 1998; Morizur *et al.* 1999). Several instances of captures in trawls in Atlantic U.S. and Canadian waters have been recorded (Hooker *et al.* 1997).

Atlantic white-sided dolphins occur in Newfoundland and Labrador waters throughout the year, although they appear to move offshore and southward to some extent during the winter. Little is known about migrations in this species. Mortality due to entrapment in heavy sea ice is occasionally reported (Ledwell 2005). The total population size of Atlantic white-sided dolphins has been estimated to be on the order of tens of thousands to low hundreds of thousands (Reeves *et al.* 1999a). In the northwest Atlantic, three substocks have been proposed for the Gulf of Maine/Bay of Fundy region, the Gulf of St. Lawrence, and the Labrador Sea, based on sightings, strandings and incidental catch records (Palka *et al.* 1997). There are very few records of Atlantic white-sided dolphins from the east coast of Nova Scotia (Gaskin 1992a; Waring *et al.* 2003).

A 1999 population estimate of 51,640 animals was obtained for the area between Georges Bank and Cabot Strait, including the Gulf of Maine/Bay of Fundy area, based on aerial and ship-based survey data (Waring *et al.* 2003). Kingsley and Reeves (1998) provided an estimate of 11,740 animals for the Gulf of St. Lawrence during a 1995 aerial survey; however, a subsequent survey in 1996, which covered only the nothern portion of the Gulf, yielded an estimate of approximately 500 animals. It is unclear what this apparent interannual regional variability in density implies for the proposed stock structure of this species in Atlantic Canadian waters. No population estimates for Atlantic white-sided dolphins are available for waters off the eastern coast of Newfoundland and Labrador.

1.5.4 - White-Beaked Dolphin Biology and Stock Status

The white-beaked dolphin is endemic to the cold temperate and subarctic waters of the north Atlantic. It is a large, robust dolphin with adults reaching up to 3 m in length and weighing up to 350 kg (Reeves *et al.* 1999b). In the northwest Atlantic, the species is found from Davis Strait to Cape Cod (Mikkelsen and Lund 1994; Reeves *et al.* 1999b). In the northeast Atlantic, it occurs from Svalbard, Iceland and the Barents Sea south at least to northern France, although the species has been reported further south on several occasions (Duguy 1981, 1988). It has been observed both in inshore and offshore waters. In Newfoundland and Labrador, the species is most common along the northern coast of the island and the waters off Labrador, but has been observed elsewhere as well (Whitehead and Glass 1985; Ledwell 2005). White-beaked dolphins occur in small groups of between 10 and 30 animals, although larger aggregations have been reported (Gunnlaugsson *et al.* 1988; Reeves *et al.* 1999b). They are often highly acrobatic at the surface, and may approach vessels (Alling and Whitehead 1987; De Boer 1989). Their impressive aerial displays have given these animals the name "jumpers" among Newfoundland fishers.

White-beaked dolphins have been reported to prey on a variety of pelagic and benthic species of fish, cephalopods and crustaceans (Dong *et al.* 1996; Kinze *et al.* 1997). The species has been reported in multispecies feeding aggregations in various parts of its range (Haase 1987; De Boer 1989; Camphuysen and Webb 1999). White-beaked dolphins have been reported caught in various types of fishing gear, including pelagic trawls, gillnets and codtraps (Bjørge *et al.* 1994; Couperus 1997; Lien *et al.* 2001). Dolphins may forage around or inside the trawls, and get captured when the trawl collapses if the vessel suddenly slows down or changes direction (Tregenza and Collet 1998; Morizur *et al.* 1999). White-beaked dolphins appear to be vulnerable to entrapment in sea ice in Newfoundland and Labrador waters (Lien *et al.* 1982, 2001; Buck and Spotte 1986; Dong *et al.* 1996). There are no published records of diving depths for the white-beaked dolphin.

Estimates of the white-beaked dolphin population for the entire north Atlantic run from the high tens of thousands to several hundred thousand animals (Reeves *et al.* 1999b). There is morphometric evidence for some degree of separation between animals in the northeast and northwest Atlantic (Mikkelsen and Lund 1994). No further information on subpopulation structure is Available online at: this time.

There are few reliable population estimates of white-beaked dolphins in Atlantic Canadian waters. Hay (1981, 1982) estimated the presence of 5,500 animals in the coastal waters of eastern Newfoundland and southeastern Labrador, based on aerial survey data. This estimate was corroborated by Alling and Whitehead (1987), who estimated a population size of 3,486 animals based on a 1982 ship-based survey off southern Labrador. Kingsley and Reeves estimated approximately 2,500 white-beaked dolphins in the Gulf of St. Lawrence during their 1995 and 1996 aerial surveys; the species was only observed in the extreme northeastern portion of the Gulf and the Strait of Belle Isle (Fig. 1.2; Kingsley and Reeves 1998). There are no abundance estimates for other areas of Newfoundland and Labrador for this species.

1.6 - Thesis Overview and Goals

The goal of this thesis is to analyse the extent of incidental catch of small cetaceans and other species of megafauna in gillnet fisheries of Newfoundland and Labrador from 2001 to 2003. Catch estimates will be based on several different modes of analysis, geographic scale, and measures of fishing effort, to determine the most suitable method given the available data. Incidental catch estimates of small cetaceans will be presented and compared to those from other areas. Uncertainty in these estimates will be described where possible. This methodology will also be applied to catches of other species, such as seals, seabirds and sharks. Finally, the management implications of these incidental catch estimates are discussed.

In the first chapter, the global problem of incidental catch in fishing gear was introduced. The impacts of fishing gear, particularly gillnets, on small cetaceans were described, and an overview of possible reasons that may lead to entanglement was presented. Subsequently, the historical development and current status of various gillnet fisheries in Newfoundland and Labrador was detailed. Finally, the biology, distribution and status of the four species of small cetaceans most commonly found in Newfoundland and Labrador waters were described, with a focus on how these characteristics might influence the likelihood of entanglement in gillnets.

In Chapter 2, all available historical records that deal with incidental catch of small cetaceans in Newfoundland and Labrador are presented. Some of these reports merely mention the occurrence of incidental capture events, while others use such records to provide estimates for larger areas of the province. A review of methods that can be used to assess incidental catch is also provided, with a focus on methods that have been put into practice in Newfoundland and Labrador.

Chapter 3 focuses in detail on the methodology used to estimate incidental catch, based on the available datasets. Various estimates are presented, using different metrics of effort, at different geographic scales, using information from the 2002 nearshore gillnet fishery for Atlantic cod as an example. The different datasets on which these estimates are based are also described. Several hypotheses are tested: 1) whether there is a difference between incidental catch estimates based on either weight (kg landed catch) or fishing effort (net-days, where 1 net-day equals a single net fishing for 24 hours); 2) whether the use of individual fishing trips as sampling units, as opposed to grouping all trips together, will affect incidental catch estimates; and 3) whether grouping data at increasing geographic scales will affect incidental catch estimates. Based on these results, a preferred method of estimating incidental catch in Newfoundkand and Labrador is presented.

In Chapter 4, the incidental catch estimation methodology developed in the previous chapter is applied to a series of nearshore and offshore gillnet fisheries active in this province, for the years 2001, 2002 and 2003. Incidental catch estimates for harbour porpoise are derived for all fisheries, with an indication of uncertainty wherever possible. Finally, these estimates are compared to published incidental catch estimates for harbour porpoises from other areas, in order to provide a broader context. The following hypotheses are tested: 1) whether incidental catch rates differ between different fisheries; 2) whether 'hot spots', or areas where catch rates are considerably higher than average, can be identified.

Chapters 5, 6 and 7 present the application of the same incidental catch methodology to estimate the concurrent incidental catch in the same fisheries during the same time period of seals, seabirds, and sharks and several large bony fish species, respectively. There are widely varying conservation concerns for these species, and so they have been separated into different, but closely associated, chapters.

Finally, in Chapter 8, the management implications of these incidental catch estimates are discussed in the broader context of the current global management trend towards an ecosystem approach to fisheries. An overview of currently existing mitigation measures is presented, and suggestions are provided on how to address the problem of incidental catch in Newfoundland and Labrador.

1.7 - References

Aarefjord, H., A. Bjørge, C.C. Kinze and I. Lindstedt. 1995. Diet of the harbour porpoise (*Phocoena phocoena*) in Scandinavian waters. Reports of the International Whaling Commission 16 (Special Issue): 211-222.

Alling, A.K. and H.P. Whitehead. 1987. A preliminary study of the status of white-beaked dolphins, *Lagenorhynchus albirostris*, and other small cetaceans off the coast of Labrador. Canadian Field-Naturalist 101 (2): 131-135.

Alverson, D.L., M.H. Freeberg, S.A. Murawski and J.G. Pope. 1994. A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper 339: 260 pp.

Alverson, D.L. and S.E. Hughes. 1996. Bycatch: from emotion to effective natural resource management. Reviews in Fish Biology and Fisheries 6: 443-462.

Andersen, L.W. 1993. The population structure of the harbour porpoise, *Phocoena phocoena*, in Danish waters and part of the North Atlantic. Marine Biology 116 (1): 1-7.

Andersen, L.W., D.E. Ruzzante, M. Walton, P. Berggren, A. Bjørge and C. Lockyer. 2001. Conservation genetics of harbour porpoises, *Phocoena phocoena,* in eastern and central North Atlantic. Conservation Genetics 2 (4): 309-324.

Anonymous. 1991. Underwater world: redfish (Ocean perch). Department of Fisheries and Oceans, DFO/4360 UW/33: 5 pp. Available online at: www.dfo-mpo.gc.ca.

Anonymous. 2005a. Canadian marine commercial fisheries landings data. Department of Fisheries and Oceans Statistical Services Unit. Available online at: http://www.dfo-mpo.gc.ca/communic/statistics/main_e.htm.

Anonymous. 2005b. Northern Cod: A failure of Canadian fisheries management. Report of the Standing Committee on Fisheries and OCeans, November 2005, Ottawa, ON, 60 pp. Available online at: http://www.parl.gc.ca/-committee/CommitteePublication.aspx?SourceId=137917.

Anonymous. 2005c. Standing Committee on Fisheries and Oceans, Edited Evidence, Session Number 047, first Session, 38th Parliament (Official version), September 28, 2005. Available online at: http://www.parl.gc.ca/-committee/CommitteePublication.aspx?SourceId=129655.

Anonymous. 2005d. A Strategy for the Recovery and Management of Cod Stocks in Newfoundland and Labrador. Canada-Newfoundland and Labrador Action Team for Cod Recovery, Department of Fisheries and Oceans (DFO) - Newfoundland and Labrador Department of Fisheries and Aquaculture, 77 pp. Available online at: http://www.dfo-mpo.gc.ca/cod-morue/nl_e.pdf.

Anonymous. 2005e. Harbour seal (*Phoca vitulina*) Western North Atlantic Stock. NOAA Marine Mammal Stock Assessment Report: 6 pp. Available online at: http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2005sehr-wn.pdf.

Au, W.W.L. 1993. The sonar of dolphins. Springer-Verlag, New York, USA.

Au, W.W.L. 1994. Sonar detection of gillnets by dolphins: Theoretical predictions. Report of the International Whaling Commission 15 (Special Issue): 565-571.

Au, W.W.L. and L. Jones. 1991. Acoustic reflectivity of nets: implications concerning incidental take of dolphins. Marine Mammal Science 7: 258-273.

Auster, P.J. 1998. A conceptual model of the impacts of fishing gear on the integrity of fish habitats. Conservation Biology 12 (6): 1198-1203.

Baird, R.W., P.J. Stacey, D.A. Duffus and K.M. Langelier. 2002. An evaluation of gray whale (*Eschrichtius robustus*) mortality incidental to fishing operations in British Columbia, Canada. Journal of Cetacean Research and Management 4 (3): 289-296.

Baraff, L.S., and T.R. Loughlin. 2000. Trends and potential interactions between pinnipeds and fisheres of New England and the U.S. west coast. Marine Fisheries Review 62(4): 1-39.

Barlow, J. and D. Hanan. 1995. An assessment of the status of the harbour porpoise in central California. Reports of the International Whaling Commission 16 (Special Issue): 123-140.

Bjørge, A., R.L.J. Brownell, G.P. Donovan and W.F. Perrin. 1994. Significant direct and incidental catches of small cetaceans. A report by the Scientific Committee of the International Whaling Commission to the United Nations Conference on Environment and Development (UNCED). Report of the International Whaling Commission 15 (Special issue): 75-130.

Bjørge, A. and N. Øien. 1995. Distribution and abundance of harbour porpoise, *Phocoena phocoena*, in Norwegian waters. Reports of the International Whaling Commission 16 (Special Issue): 89-98.

Bjørge, A., N. Øien, S. Hartvedt and G. Bothun. 2002. Dispersal and bycatch mortality in gray, *Halichoerus grypus*, and harbor, *Phoca vitulina*, seals tagged at the Norwegian coast. Marine Mammal Science 18 (4): 963-976.

Börjesson, P. and P. Berggren. 1997. Morphometric comparisons of skulls of harbour porpoises (*Phocoena phocoena*) from the Baltic, Kattegat and Skagerrak seas. Canadian Journal of Fisheries and Aquatic Sciences 75: 280-287.

Börjesson, P., P. Berggren and B. Ganning. 2003. Diet of harbour porpoises in the Kattegat and Skagerrak Seas: Accounting for individual variation and sample size. Marine Mammal Science 19: 38-58.

Börjesson, P. and A. Read. 2003. Variation in timing of conception between populations of the harbour porpoise (*Phocoena phocoena*). Journal of Mammalogy 84: 948-955.

Bravington, M.V. and K.D. Bisack. 1996. Estimates of harbour porpoise bycatch in the Gulf of Maine sink gillnet fishery, 1990-1993. Report of the International Whaling Commission 46: 567-574.

Brodie, P.F. 1995. The Bay of Fundy/Gulf of Maine harbour porpoise (*Phocoena phocoena*): some consideration regarding species interactions, energetics, density dependence and bycatch. Reports of the International Whaling Commission 16 (Special Issue): 181-187.

Brothers, N.P., J. Cooper and S. Løkkeborg. 1999. The incidental catch of seabirds by longline fisheries: worldwide review and technical guidelines for mitigation. FAO Fisheries Circular, 100 pp. Available online at: http://-www.fao.org/figis/servlet/static?xml=ipoa_seabirds.xml&dom=org&-xp_nav=2.

Buck, J.D. and S. Spotte. 1986. Microbiology of captive White-beaked Dolphins (*Lagenorhynchus albirostris*) with comments on epizootics. Zoo Biology 5: 321-329.

Camphuysen, C.J. and A. Webb. 1999. Multi-species feeding associations in North Sea seabirds: Jointly exploiting a patchy environment. Ardea 87 (2): 177-198.

Carwardine, M. 1995. Eyewitness Handbooks: Whales, Dolphins and Porpoises, Dorling Kindersley, New York, NY.

Caswell, W., S. Brault, A.J. Read and T.D. Smith. 1998. Harbor porpoise and fisheries: an uncertainty analysis of incidental mortality. Ecological Applications 8 (4): 1226-1238.

CeTAP. 1982. A characterization of marine mammals and turtles in the mid and North American areas of the U.S. Outer Continental Shelf. Final Report AA551-CT8-48 of Cetacean and Turtle Assessment Programme (CeTAP) to the Bureau of Land Management, U.S. Dept. of the Interior, Washington, D.C., U.S.A.; 538 pp.

Christensen, O. and W.H. Lear. 1977. Bycatches in salmon drift-nets at west Greenland in 1972. Kommissionen for Videnskabelige Undersøgelser i Grønland 205 (5): 5-37.

Chivers, S.J., A.E. Dizon, P.J. Gearin and K.M. Robertson. 2002. Small-scale population structure of eastern North Pacific harbour porpoises (*Phocoena phocoena*) indicated by molecular genetic analysis. Journal of Cetacean Research and Management 4 (2): 111-122.

Clua, E. and F. Grosvalet. 2001. Mixed-species feeding aggregation of dolphins, large tunas and seabirds in the Azores. Aquatic Living Resources 14 (1): 11-18.

Clucas, I. 1997. A study of the options for utilization of bycatch and discards from marine capture fisheries. FAO Fisheries Circular 928: 59 pp.

Colbourne, E., B. Deyoung, S. Narayanan and J. Helbig. 1997. Comparison of hydrography and circulation on the Newfoundland Shelf during 1990-1993 with the long-term mean. Canadian Journal of Fisheries and Aquatic Sciences 54 (Suppl. 1): 68-80.

Collins, M.A.J. 1976. The lumpfish (*Cyclopterus lumpus* L.) in Newfoundland waters. Canadian Field-Naturalist 90: 64-67.
Connor, R.C., M.R. Heithaus, P. Berggren and J.L. Miksis. 2000. "Kerplunking": Surface fluke-splashes during shallow-water bottom foraging by bottlenose dolphins. Marine Mammal Science 16 (3): 646-653.
Corkeron, P.J., M.M. Bryden and K.E. Hedstrom. 1990. Feeding by bottlenose dolphins in association with trawling operations in Moreton Bay, Australia. Pages 329-336 in S. Leatherwood and R.R. Reeves (eds.): The Bottlenose Dolphin. Academic Press, Inc., San Diego, CA, U.S.A.
COSEWIC. 2003a. COSEWIC assessment and update status report on the harbour porpoise *Phocoena phocoena* (Northwest Atlantic population) in Canada. Committee on the Status of Endangered Wildlife in Canada, vii + 30 pp. Available online at: http://www.sararegistry.gc.ca/virtual_sara/-files/cosewic/sr_harbour_porpoise_e.pdf.
COSEWIC. 2003b. COSEWIC assessment and update status report on the harbour porpoise *Phocoena phocoena* (Pacific Ocean population) in Canada. Committee on the Status of Endangered Wildlife in Canada, vi + 22 pp. Available online at: www.sararegistry.gc.ca/status/status_e.cfm.
COSEWIC. 2003c. COSEWIC assessment and update status report on the Atlantic cod *Gadus morhua* in Canada. Committee on the Status of Endangered Wildlife in Canada: xi + 76 pp. Available online at: www.sararegistry.gc.ca/status/status_e.cfm.
Couperus, A.S. 1997. Interactions between Dutch midwater trawl and Atlantic White-sided Dolphins (*Lagenorhynchus acutus*) southwest of Ireland. Journal of Northwest Atlantic Fisheries Science 22: 209-218.
Cox, T.M., A.J. Read, D. Swanner, K. Urian and D. Waples. 2003. Behavioral responses of bottlenose dolphins, *Tursiops truncatus*, to gillnets and acoustic alarms. Biological Conservation 115: 203-212.
Crespo, E.A., J.F. Corcuera and A.L. Cazorla. 1994. Interactions between marine mammals and fisheries in some coastal fishing areas in Argentina. Report of the International Whaling Commission 15 (Special Issue): 269-281.
D'Agrosa, C., C.E. Lennert-Cody and O. Vidal. 2000. Vaquita bycatch in Mexico's artisanal fisheries: driving a small population to extinction. Conservation Biology 14 (4): 1110-1119.
Dawson, S., F. Pichler, E. Slooten, K. Russell and C.S. Baker. 2001. The North Island Hector's dolphin is vulnerable to extinction. Marine Mammal Science 17 (2): 366-371.
Dawson, S.M. and E. Slooten. 2005. Management of gillnet bycatch of cetaceans in New Zealand. Journal of Cetacean Research and Management 7 (1): 59-64.
Dayton, P.K., S.F. Thrush, M.T. Agardy and R.J. Hofman. 1995. Environmental effects of marine fishing. Aquatic Conservation: Marine and Freshwater Ecosystems 5: 205-232.

De Boer, R. 1989. Waarneming van een gemengde groep witflankdolfijnen *Lagenorhynchus acutus* en witsnuitdolfijnen *L.albirostris* in de centrale Noordzee. Lutra 32 (2): 181-184.

Dehnhardt, G., B. Mauck and H. Bleckmann. 1998. Seal whiskers detect water movements. Nature 394(6690): 235-236.

Dehnhardt, G., B. Mauck, W. Hanke and H. Bleckmann. 2001. Hydrodynamic trail-following in harbor seals (*Phoca vitulina*). Science 293 (5527): 102-104.

DeMaster, D.P., C.W. Fowler, S.L. Perry and M.E. Richlen. 2001. Predation and competition: The impact of fisheries on marine-mammal populations over the next one hundred years. Journal of Mammalogy 82 (3): 641-651.

DeYoung, B. and G.A. Rose. 1993. On recruitment and distribution of Atlantic cod (*Gadus morhua*) off Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences 50 (12): 2729-2740.

DFO [Department of Fisheries and Oceans]. 1993a. Atlantic Cod. Department of Fisheries and Oceans, Underwater World factsheet: 8 pp.

DFO [Department of Fisheries and Oceans]. 1993b. Atlantic Herring. Underwater World factsheet: 8 pp.

DFO [Department of Fisheries and Oceans]. 1999. Newfoundland Region groundfish overview. DFO Canadian Science Advisory Secretariat Stock Status Report A2-19, 12 pp.

DFO [Department of Fisheries and Oceans]. 2002a. Lumpfish in NAFO Division 3P. DFO Canadian Science Advisory Secretariat Stock Status Report A2-17: 3 pp.

DFO [Department of Fisheries and Oceans]. 2002b. White hake in Division 3L, 3N, 3O, and Subdivision 3Ps. DFO Canadian Science Advisory Secretariat Stock Status Report A2-06: 5 pp. Available online at: http://www.dfo-mpo.gc.ca/csas/Csas/status/2002/SSR2002_A2-06e.pdf.

DFO [Department of Fisheries and Oceans]. 2003. Monkfish in Divisions 3L, 3N, 3O and Subdivision 3Ps. DFO Canadian Science Advisory Secretariat Stock Status Report 2003/045, 5 pp. Available online at: http://www.dfo-mpo.gc.ca/csas.

DFO [Department of Fisheries and Oceans]. 2004a. East and Southeast Newfoundland Atlantic Herring. DFO Canadian Science Advisory Secretariat Stock Status Report, 2004/046: 20 pp. Available online at: http://www.dfo-mpo.gc.ca/csas.

DFO [Department of Fisheries and Oceans]. 2004b. Newfoundland and Labrador Region Groundfish Stock Updates. DFO Canadian Science Advisory Secretariat Stock Status Report, 2004/047: 1-10 pp. Available online at: www.dfo-mpo.gc.ca/csas.

DFO [Department of Fisheries and Oceans]. 2004c. The northern Gulf of St. Lawrence (3Pn, 4RS) cod in 2003. Department of Fisheries and Oceans, Canadian Science Advisory Secretariat Stock Status Report, 2004/019: 11 pp.

DFO [Department of Fisheries and Oceans]. 2004d. Subdivision 3Ps Cod. DFO Canadian Science Advisory Secretariat Stock Status Report, 2004/039: 15 pp.
DFO [Department of Fisheries and Oceans]. 2004e. Unit 2 Redfish. DFO Canadian Scientific Advisory Secretariat Stock Status Report 2004/016, 4 pp.
DFO [Department of Fisheries and Oceans]. 2004f. West Coast of Newfoundland Atlantic Herring (Division 4R) in 2003. DFO Canadian Scientific Advisory Secretariat Stock Status Report, 2004/017: 10 pp.
DFO [Department of Fisheries and Oceans]. 2004d. Allowable Harm Assessment for Newfoundland and Labrador Cod. DFO Canadian Science Advisory Secretariat Stock Status Report, 2004/042: 13 pp.
DFO [Department of Fisheries and Oceans]. 2006a. Northern Bottlenose Whale (Scotian Shelf) and Channel Darter protected under the Species at Risk Act. Department of Fisheries and Oceans News Release, 1 pp. Available online at: http://www.dfo-mpo.gc.ca/media/newsrel/2006/hq-ac10_e.htm?template=print.
DFO [Department of Fisheries and Oceans]. 2006b. New Government Programme to test the health of Cod Stocks. Department of Fisheries and Oceans News Release, 1 pp. Available online at: http://www.dfo-mpo.gc.ca/media/newsrel/2006/hq-ac14_e.htm.
Dolar, L.L. 1994. Incidental takes of small cetaceans in fisheries in Palawan. Central Visayas and northern Mindanao in the Philippines. Reports of the International Whaling Commission 15 (Special Issue): 355-363.
Dong, J.H., J. Lien, D. Nelson and K. Curren. 1996. A contribution to the biology of the White-beaked dolphin, *Lagenorhynchus albirostris*, in waters off Newfoundland. Canadian Field-Naturalist 110: 278-287.
Donovan, G.P. and A. Bjørge. 1995. Harbour Porpoises in the North Atlantic: edited extract from the Report of the IWC Scientific Committee, Dublin 1995. Reports of the International Whaling Commission 16 (Special Issue): 3-25.
Drinkwater, K.F. and D.G. Mountain. 1997. Climate and oceanography. Pages 3-26 in R.L. Kendall (ed.): Northwest Atlantic Groundfish: Perspectives on a Fishery Collapse. American Fisheries Society, Bethesda, MD, U.S.A.
Duguy, R. 1981. *Lagenorhynchus albirostris* (Cetacea: Odontoceti): Espèce nouvelle pour la faune de France. Mammalia 45 (3): 387-388.
Duguy, R. 1988. Cetaces et pinnipedes observes sur les cotes Francaises en 1987. International Council for the Exploration of the Sea (ICES), N:2: 1-4.
Evans, P.G.H. 1980. Cetaceans in British waters. Mammal Review 10: 1-52.
Evans, W.E. 1994. Common dolphin, White-bellied porpoise *Delphinus delphis* Linnaeus, 1758. Page 191-224 In: Handbook of marine mammals. 5. S. H. Ridgway and R. Harrison (Ed.), Academic Press, London, U.K.
FAO [Food and Agriculture Organization of the United Nations]. 1978. FAO Catalogue of Fishing Gear Designs. Rome, Italy: 160 pp.

FAO [Food and Agriculture Organization of the United Nations]. 1998. The State of World Fisheries and Aquaculture 1998. Rome, Italy.

FAO [Food and Agriculture Organization of the United Nations]. 2004. The State of World Fisheries and Aquaculture (SOFIA) 2004. Rome, Italy: 153 pp.

Felt, L.F. and L.W. Locke. 1995. "It were well to live mainly off fish": The collapse of Newfoundland's fishery and beyond. Pages 197-236 in L. Felt (ed.): The North Atlantic Fisheries: Successes, failures and challenges. Volume 3. The Institute of Island Studies, Charlottetown, P.E.I., Canada.

Fontaine, P.M., M.O. Hammill, C. Barrette and M.C. Kingsley. 1994. Summer diet of the harbour porpoise (*Phocoena phocoena*) in the estuary and the Northern Gulf of St. Lawrence. Canadian Journal of Fisheries and Aquatic Sciences 51 (1): 172-178.

Freese, L., P.J. Auster, J. Heifetz and B.L. Wing. 1999. Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska. Marine Ecology Progress Series 182: 119-126.

Fridman, A.L. 1986. Calculations for fishing gear designs. FAO Fishing Manuals, Fishing News Books Ltd., Farnham, Surrey, UK. 241 pp.

Gannon, D.P., J.E. Craddock and A.J. Read. 1998. Autumn food habits of harbor porpoises, *Phocoena phocoena*, in the Gulf of Maine. Fishery Bulletin 96 (3): 428-437.

Gao, A. and D.E. Gaskin. 1996. Geographical variation in metric skull characters among proposed subpopulations and stocks of harbor porpoise, *Phocoena phocoena*, in the western North Atlantic. Marine Mammal Science 12(4): 516-527.

Gaskin, D.E. 1984. The harbour porpoise *Phocoena phocoena* (L.): regional populations, status, and information on direct and indirect catches. Reports of the International Whaling Commission 34: 569-586.

Gaskin, D.E. 1991. COSEWIC update status report on the harbour porpoise *Phocoena phocoena* (Northwest Atlantic population) in Canada. Committee on the Status of Endangered Wildlife in Canada: 60 pp.

Gaskin, D.E. 1992a. Status of the Atlantic white-sided dolphin, *Lagenorhynchus acutus*, in Canada. Canadian Field-Naturalist 106 (1): 64-72.

Gaskin, D.E. 1992b. Status of the Common Dolphin, *Delphinus delphis*, in Canada. Canadian Field-Naturalist 106 (1): 55-63.

Gaskin, D.E. 1992c. Status of the harbour porpoise, *Phocoena phocoena*, in Canada. Canadian Field-Naturalist 106 (1): 36-54.

Gaskin, D.E. and A.P. Watson. 1985. The harbor porpoise, *Phocoena phocoena*, in Fish Harbour, New Brunswick, Canada: occupancy, distribution, and movements. Fishery Bulletin 83 (3): 427-442.

Gilbert, J. R. and K. M. Wynne. 1985. Harbor seal populations and fisheries interactions with marine mammals in New England, 1984. NOAA Interim Report, NA-84-EAC-00070, to NMFS, Northeast Fisheries Science Center, Woods Hole, MA. 15 pp.

Goodson, D., M. Klinowska and P.R.S. Bloom. 1994. Enhancing the acoustic detectability of gillnets. Report of the International Whaling Commission 15 (Special Issue): 585-595.

Gosliner, M.L. 1999. The Tuna-Dolphin Controversy. Pages 120-155 in J.R. Twiss Jr. and R.R. Reeves (eds.): Conservation and management of marine mammals. Smithsonian Institution Press, Washington, D.C., U.S.A.

Gowans, S. and H. Whitehead. 1995. Distribution and habitat partitioning by small odontocetes in the Gully, a submarine canyon on the Scotian Shelf. Canadian Journal of Zoology 3: 1599-1608.

Gunnlaugsson, T., J. Sigurjónsson and G.P. Donovan. 1988. Aerial survey of cetaceans in the coastal waters off Iceland, June-July 1986. International Whaling Commission Report of the Commission 38: 489-500.

Haase, B.J.M. 1987. A mixed herd of white-beaked dolphins *Lagenorhynchus albirostris* and white-sided dolphins *L.acutus* in the southern North Sea. Lutra 30: 105-106.

Hall, M.A. 1996. On bycatches. Review of Fish Biology and Fisheries 8: 1-34.

Hall, M.A., D.L. Alverson and K.I. Metuzals. 2000. By-Catch: Problems and Solutions. Marine Pollution Bulletin 41 (1-6): 204-219.

Hatakeyama, Y., K. Ishii, T. Akamatsu, H. Soeda, T. Shimamura and T. Kojima. 1994. A review of studies on attempts to reduce the entanglement of the Dall's porpoise, *Phocoenoides dalli*, in the Japanese salmon gillnet fishery. Report of the International Whaling Commission 15 (Special Issue): 549-563.

Hay, K. 1981. Line-transect estimates of whale abundance In the Newfoundland-Labrador area, 1980. Department of Fisheries and Oceans Research Document: 35 pp.

Hay, K. 1982. Aerial line-transect estimates of abundance of humpback, fin, and long-finned pilot whales in the Newfoundland-Labrador area. Report of the International Whaling Commission 32: 475-486.

Heyning, J.E. and W.F. Perrin. 1994. Evidence for two species of common dolphins (genus *Delphinus*) from the eastern North Pacific. Natural History Museum of Los Angeles County Contributions in Science 442: 1-35.

Hill, B.J. and T.J. Wassenberg. 1990. Fate of discards from prawn trawlers in Torres Strait. Australian Journal of Marine and Freshwater Research 41: 53-64.

Hood, C.C. 2001. Incidental capture of harbour porpoise, *Phocoena phocoena*, in three gillnet fisheries of the northwest Atlantic: investigation of possible causes. Ph.D. thesis, Biopsychology, Memorial University of Newfoundland, St. John's, NL, 375 pp.

Hooker, S. K., R. W. Baird and M. A. Showell. 1997. Cetacean strandings and bycatches in Nova Scotia, Eastern Canada, 1991-1996. Meeting Document SC/49/O5 submitted to the 1997 International Whaling Commission meeting in Bournemouth, UK.

Hutchings, J.A. and R.A. Myers. 1994. What can be learned from the collapse of a renewable resource? Atlantic cod, *Gadus morhua*, of Newfoundland and Labrador. Canadian Journal of Fisheries and Aquatic Sciences 51 (9): 2126-2146.
Hutchings, J.A. and R.A. Myers. 1995. The biological collapse of Atlantic Cod off Newfoundland and Labrador: An exploration of historical changes in exploitation, harvesting technology, and management. Pages 37-93 in: The North Atlantic fisheries: Successes, failures and challenges. L. Felt (Ed.), The Institute of Island Studies, Charlottetown, P.E.I., Canada.
IWC. 1994. Report of the Workshop on Mortality of Cetaceans in Passive Fishing Nets and Traps. Reports of the International Whaling Commission 15 (Special Issue): 6-57.
IWC. 1996. Report of the Sub-Committee on Small Cetaceans. Reports of the International Whaling Commission 46: 160-179.
IWC. 2000. Annex 1: Report of the Sub-Committee on Small Cetaceans. Journal of Cetacean Research and Management 2 (Supplement): 235-263.
IWC. 2002. Report of the standing subcommittee on small cetaceans. Journal of Cetacean Research and Management 4 (Supplement): 325-338.
Jefferson, T.A. and B.E. Curry. 1994. A global review of porpoise (Cetacea, Phocoenidae) mortality in gillnets. Biological Conservation 67(2): 167-183.
Jefferson, T.A. and K. Van Waerebeek. 2002. The taxonomic status of the nominal dolphin species *Delphinus tropicalis* van Bree, 1971. Marine Mammal Science 18: 787-818.
Jennings, S., T.A. Dinmore, D.E. Duplisea, K.J. Warr and J.E. Lancaster. 2001a. Trawling disturbance can modify benthic production processes. Journal of Animal Ecology 70 (3): 459-475.
Jennings, S., J.K. Pinnegar, N.V.C. Polunin and K.J. Warr. 2001b. Impacts of trawling disturbance on the trophic structure of benthic invertebrate communities. Marine Ecology Progress Series 213: 127-142.
Johnston, D.W. and A.J. Westgate. 2005. Effects of fine-scale oceanographic features on the distribution and movements of harbour porpoises *Phocoena phocoena* in the Bay of Fundy. Marine Ecology Progress Series 295: 279-293.
Kaiser, M.J. 1998. Significance of bottom-fishing disturbance. Conservation Biology 12 (6): 1230-1235.
Kaiser, M.J., B. Bullimore, P. Newman, K. Lock and S. Gilbert. 1996. Catches in 'ghost fishing' set nets. Marine Ecology Progress Series 145: 11-16.
Kaiser, M.J., K. Cheney, F.E. Spence, D.B. Edwards and K. Radford. 1999. Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure VII. The effects of trawling disturbance on the fauna associated with the tubeheads of serpulid worms. Fisheries Research 40 (2): 195-205.
Kaiser, M.J., D.B. Edwards, P.J. Armstrong, K. Radford, N.E.L. Lough, R.P. Flatt and H.D. Jones. 1998. Changes in megafaunal benthic communities in

different habitats after trawling disturbance. ICES Journal of Marine Science 55 (3): 353-361.
Kastelein, R.A., W.W.L. Au and D. de Haan. 2000. Detection distances of bottom-set gillnets by harbour porpoises (*Phocoena phocoena*) and bottlenose dolphins (*Tursiops truncatus*). Marine Environmental Research 49 (4): 359-375.
Kastelein, R.A., D. de Haan, C. Staal, S.H. Nieuwstraten and W.C. Verboom. 1995a. Entanglement of harbour porpoises (*Phocoena phocoena*) in fishing nets. Pages 91-156 in P.E. Nachtigall, J. Lien, W.W.L. Au and A.J. Read (eds.): Harbour porpoises: Laboratory studies to reduce bycatch. De Spil Publishers, Woerden, The Netherlands.
Kastelein, R.A., J.A. Thomas and P.E. Nachtigall (Eds.). 1995b. Sensory systems of aquatic mammals. De Spil Publishers, Woerden, The Netherlands.
Kastelein, R.A., N.M. Schooneman, W.W.L. Au, W. C. Verboom and N. Vaughan. 1997. The ability of a harbour porpoise (*Phocoena phocoena*) to discriminate between objects buried in sand. Pages 329-342 in: The biology of the harbour porpoise. A.J. Read, P.R. Wiepkema and P.E. Nachtigall (Ed.), De Spil Publ., Woerden, The Netherlands.
Kastelein, R.A., W.W.L. Au and D. deHaan. 2000. Detection distances of bottom-set gillnets by harbour porpoises (*Phocoena phocoena*) and bottlenose dolphins (*Tursiops truncatus*). Marine Environmental Research 49(4): 359-375.
Kenchington, E.L.R., J. Prena, K.D. Gilkinson, D.C. Gordon, K. MacIsaac, C. Bourbonnais, P.J. Schwinghamer, T. W. Rowell, D.L. McKeown and W.P. Vass. 2001. Effects of experimental otter trawling on the macrofauna of a sandy bottom ecosystem on the Grand Banks of Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences 58 (6): 1043-1057.
Kingsley, M.C.S. and R.R. Reeves. 1998. Aerial surveys of cetaceans in the Gulf of St. Lawrence in 1995 and 1996. Canadian Journal of Zoology 76 (8): 1529-1550.
Kinze, C.C. 1995. Exploitation of harbour porpoises (*Phocoena phocoena*) in Danish waters: a historical review. Reports of the International Whaling Commission 16 (Special Issue): 141-153.
Kinze, C.C., M. Addink, C. Smeenk, M.G. Hartmann, H.W. Richards, R.P. Sonntag and H. Benke. 1997. The white-beaked dolphin (*Lagenorhynchus albirostris*) and the white-sided dolphin (*Lagenorhynchus acutus*) in the North and Baltic seas: review of available information. Reports of the International Whaling Commission 47: 675-681.
Knowlton, A.R. and S.D. Kraus. 2001. Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western North Atlantic Ocean. Journal of Cetacean Research and Management 2 (Special Issue): 193-208.

Koschinski, S. 2002. Current knowledge of harbour porpoises (*Phocoena phocoena*) in the Baltic Sea. Ophelia 55 (3): 167-197.

Kraus, S.D. 1990. Rates and potential causes of mortality in North Atlantic right whales (*Eubalaena glacialis*). Marine Mammal Science 6: 278–291.

Kulka, D.W. and C.M. Miri. 2001. The status of Monkfish (*Lophius americanus*) in NAFO Divisions 2J, 3K, 3L, 3N, 3O and Subdivision 3Ps. Canadian Science Advisory Secretariat Research Document 2001/004: 40 pp.

Lauriano, G., C.M. Fortuna, G. Moltedo and G. Notarbartolo di Sciara. 2004. Interactions between common bottlenose dolphins (*Tursiops truncatus*) and the artisanal fishery in Asinara Island National Park (Sardinia): assessment of catch damage and economic loss. Journal of Cetacean Research and Management 6 (2): 165-173.

Lawson, J. 2006. Science and implementation considerations of mitigation techniques to reduce small cetacean bycatch in fisheries. A workshop in association with the 16th Biennial Conference on the Biology of Marine Mammals, San Diego, CA, USA: 26 pp.

Lear, W.H. 1998. History of Fisheries in the Northwest Atlantic: the 500-year perspective. Journal of Northwest Atlantic Fisheries Science 23: 41-73.

Lear, W.H. and O. Christensen. 1975. By-catches of harbour porpoise (*Phocoena phocoena*) in salmon driftnets at West Greenland in 1972. Journal of the Fisheries Research Board of Canada 32: 1223-1228.

Lear, W.H. and L.S. Parsons. 1993. History and management of the fishery for northern cod in NAFO Divisions 2J, 3K and 3L. Canadian Bulletin of Fisheries and Aquatic Sciences 226: 55-89.

Ledwell, W. 2005. Whales and Dolphins of Newfoundland & Labrador. Boulder Publications Ltd., St. John's, NL, Canada.

Lennert-Cody, C.E., M. Minami and M.A. Hall. 2004. Incidental mortality of dolphins in the eastern Pacific Ocean purse-seine fishery: correlates and their spatial association. Journal of Cetacean Research and Management 6 (2): 151-163.

Lens, S. 1997. Interactions between marine mammals and deep water trawlers in the NAFO regulatory area. ICES CM 1997/Q:8. 10 pp.

Lesage, V., J. Keays, S. Turgeon and S. Hurtubise. 2004. Incidental catches of harbour porpoises (*Phocoena phocoena*) in the gillnet fishery of the Estuary and Gulf of St. Lawrence in 2000-2002. Canadian Technical Report of Fisheries and Aquatic Sciences 2552: 37.

Lescrauwaet, A.-C. and J. Gibbons. 1994. Mortality of Small Ceaceans and the Crab Bait fishery in the Magellanes area of Chile since 1980. Report of the International Whaling Commission 15 (Special Issue): 485-494.

Levenson, D.H. and R.J. Schusterman. 1999. Dark adaptation and visual sensitivity in shallow and deep-diving pinnipeds. Marine Mammal Science 15(4): 1303-1313.

Lewison, R.L., L.B. Crowder, A.J. Read and S.A. Freeman. 2004. Understanding impacts of fisheries bycatch on marine megafauna. Trends in Ecology and Evolution 19 (11): 598-604.
Lien, J. 1980. Whale entrapment in inshore fishing gear in Newfoundland. Final Report. Memorial University of Newfoundland, 315 pp.
Lien, J. 1983. Incidental catch of harbour porpoise (*Phocoena phocoena*) off Newfoundland and Labrador. COSEWIC Working Paper, 2 pp.
Lien, J. 1985. Wet and fat: whales and seals of Newfoundland and Labrador, Breakwater Books, Ltd., St. John's, Newfoundland.
Lien, J. 1989. Incidental catch of harbour porpoise (*Phocoena phocoena*) in waters off Newfoundland and Labrador: some estimates based on present data and a request for further study. Workshop on harbour porpoise, St. Andrews, NB, Canada: 12 pp.
Lien, J. 1994. Entrapments of large cetaceans in passive inshore fishing gear in Newfoundland and Labrador (1979-1990). Reports of the International Whaling Commission 15 (Special Issue): 149-157.
Lien, J. 2001. Incidental bycatch of harbour porpoise in Newfoundland and Labrador-as we know it. Paper presented at the Department of Fisheries and Oceans' International Harbour Porpoise Workshop, Dartmouth, NS, Canada, 26-28 March 2001: 12 pp.
Lien, J., J.H. Dong, L. Baraff, J. Harvey and K. Chu. 1982. Whale entrapment in inshore fishing gear during 1982: a preliminary report to Fisheries and Oceans Canada, September 20, 1982. Newfoundland Institute for Cold Ocean Science; Canada. Dept. of Fisheries and Oceans. Newfoundland Region, 36 pp.
Lien, J., D. Nelson and D.J. Hai. 2001. Status of the white-beaked dolphin, *Lagenorhynchus albirostris*, in Canada. Canadian Field-Naturalist 115 (1): 118-126.
Lien, J., W. Ledwell and J. Huntington. 1989a. Incidental entrapments by inshore fishing gear reported in 1989: A preliminary report to the Development Branch, Fisheries and Oceans Canada - Newfoundland region; and the Newfoundland and Labrador Department of Fisheries. Memorial University of Newfoundland: 35 pp.
Lien, J., G.B. Stenson and I. Hsun-Ni. 1989b. A review of incidental entrapment of seabirds, seals and whales in inshore fishing gear in Newfoundland and Labrador: a problem for fishermen and fishing gear designers. Proceedings of the 1988 World Symposium on Fishing Gear and Fishing Vessel Design, Newfoundland and Labrador Institute of Fisheries and Marine Technology, St. John's, NF: 67-71.
Lien, J., S. Todd and J. Guigne. 1990. Inferences about perception in large cetaceans, especially humpback whales, from incidental catches in fixed fishing gear, enhancement of nets by "alarm" devices, and the acoustics of fishing gear. Pages 347-362 in J.A. Thomas and R.A. Kastelein (eds.):

Sensory abilities of cetaceans: Laboratory and field evidence. Plenum Press, New York, NY, USA.
Lockyer, C. 1995. Investigation of aspects of the life history of the harbour porpoise, *Phocoena phocoena*, in British waters. Report of the International Whaling Commission 16 (Special Issue): 189-209.
Lockyer, C. 2003. Harbor porpoises (*Phocoena phocoena*) in the North Atlantic: Biological parameters. Pages 71-90 in T. Haug, G. Desportes, G.A. Víkingsson and L. Witting (eds.): Harbour porpoises in the North Atlantic. NAMMCO Scientific Publications Volume 5, Tromsø, Norway.
Lockyer, C., G. Desportes, M. Amundin and D. Goodson. 2001. The tail of EPIC - Elimination of harbour Porpoise Incidental Catch. Final Report to the European Commission of Project No DG XIV 97/00006.
Lockyer, C. and C.C. Kinze. 2003. Status, ecology and life history of harbour porpoise (*Phocoena phocoena*), in Danish waters. Pages 143-176 in T. Haug, G. Desportes, G.A. Víkingsson and L. Witting (eds.): Harbour porpoises in the North Atlantic. NAMMCO Scientific Publications Volume 5, Tromsø, Norway.
Lunneryd, S. G. and H. Westerberg. 1997. Bycatch of, and gear damage by, grey seal (*Halichoerus grypus*) in Swedish waters. ICES CM 1997/Q: 11 pp.
Macdonald, R.D.S. 1984. Canadian fisheries policy and the development of Atlantic coast groundfisheries management. Pages i-252 in A.J. Hanson (ed.): Atlantic fisheries and coastal communities: Fisheries decision-making case studies. Dalhousie Ocean Studies Programme, Halifax, N.S., Canada.
Manly, B.F.J., A. Seyb and D.J. Fletcher. 2002. Bycatch of fur seals (*Arctocephalus forsteri*) in New Zealand fisheries, 1990/91-1995/96, and observer coverage. New Zealand Department of Conservation Science Internal Series #41: 40 pp.
Mate, B.R., K.M. Stafford, R. Nawojchik and J.L. Dunn. 1994. Movements and dive behaviour of a satellite-monitored Atlantic white-sided dolphin (*Lagenorhynchus acutus*) in the Gulf of Maine. Marine Mammal Science 10 (1): 116-121.
McLellan, W.A., H.N. Koopman, S.A. Rommel, A.J. Read, C.W. Potter, J.R. Nicolas, A.J. Westgate and D.A. Pabst. 2002. Ontogenetic allometry and body composition of harbour porpoises (*Phocoena phocoena*, L.) from the western North Atlantic. Journal of the Zoological Society of London 257 (4): 457-471.
Mikkelsen, A.M.H. and A. Lund. 1994. Intraspecific variation in the dolphins *Lagenorhynchus albirostris* and *L. acutus* (Mammalia: Cetacea) in metrical and non-metrical skull characters, with remarks on occurrence. Journal of Zoology (London) 234 (2): 289-299.
Morizur, Y., S.D. Berrow, N.J.C. Tregenza, A.S. Couperus and S. Pouvreau. 1999. Incidental catches of marine-mammals in pelagic trawl fisheries of the northeast Atlantic. Fisheries Research 41 (3): 297-307.

Myers, R.A. and B.Sjare. 1995. An analysis of lumpfish from data on individual fishermen in the Newfoundland Region. DFO Atlantic Fisheries Research Document, 95/66: 12 pp.

Nédélec, C. and J. Prado. 1990. Definition and classification of fishing gear categories. FAO Fisheries Technical Paper 222: 111 pp.

Neimanis, A.S., H.N. Koopman, A.J. Westgate, L.D. Murison and A.J. Read. 2004. Entrapment of harbour porpoises (*Phocoena phocoena*) in herring weirs in the Bay of Fundy, Canada. Journal of Cetacean Research and Management 6 (1): 7-17.

Neimanis, A.S., A.J. Read, R.A. Foster and D.E. Gaskin. 2000. Seasonal regression in testicular size and histology in harbour porpoises (*Phocoena phocoena*, L.) from the Bay of Fundy and Gulf of Maine. Journal of Zoology 250: 221-229.

Neis, B., D.C. Schneider, L. Felt, R.L. Haedrich, J. Fischer and J.A. Hutchings. 1999. Fisheries assessment: What can be learned from interviewing resource users? Canadian Journal of Fisheries and Aquatic Sciences 56 (10): 1949-1963.

NEFMC [New England Fishery Management Council]. 2004. Catch and Bycatch in the Herring Fishery-Summary of Available Data. New England Fishery Management Council, Newburyport, Massachusetts.

NMFS [National Marine Fisheries Service]. 1997. Investigation of scientific information on the impacts of California sea lions and Pacific harbor seals on salmonids and on the coastal ecosystems of Washington, Oregon, and California. U.S. Dep. Commerce, NOAA Technical Memorandum, NMFS-NWFSC-28: 172 pp. Available online at: http://www.nwfsc.noaa.gov/-publications/techmemos/tm28/tm28.htm#toc.

Norris, K.S., J.H. Prescott, P.V. Asa-Dorian and P. Perkins. 1961. An experimental demonstration of echolocation behavior in the porpoise, *Tursiops truncatus* (Montagu). Biological Bulletin (Woods Hole) 120: 163-176.

Northridge, S.P. 1984. World review of interactions between marine mammals and fisheries. FAO Fisheries Technical Paper 251: 197 pp.

Northridge, S.P. 1991. An updated world review of interactions between marine mammals and fisheries. FAO Fisheries Technical Paper 251/Supplement 1: 64 pp.

Northridge, S.P. and R.J. Hofman. 1999. Marine Mammal Interactions with Fisheries. Pages 99-119 in J.R. Twiss Jr. and R.R. Reeves (eds.): Conservation and management of marine mammals. Smithsonian Institution Press, Washington, D.C., USA.

Northridge, S.P., M.L. Tasker, A. Webb and J.M. Williams. 1995. Distribution and relative abundance of harbor porpoises (*Phocoena phocoena* L), white-beaked dolphins (*Lagenorhynchus albirostris* Gray), and minke whales (*Balaenoptera acutorostrata* Lacepede) around the British Isles. ICES Journal of Marine Science 52: 55-66.

Ohizumi, H., M. Yoshioka, K. Mori and N. Miyazaki. 1998. Stomach contents of common dolphins (*Delphinus delphis*) in the pelagic western North Pacific. Marine Mammal Science 14 (4): 835-844.

Ohsumi, S. 1975. Incidental catch of cetaceans with salmon gillnet. Journal of the Fisheries Research Board of Canada 32: 1229-1235.

Otani, S., Y. Naito, A. Kawamura, M. Kawasaki, S. Nishiwaki and A. Kato. 1998. Diving behavior and performance of harbor porpoises, *Phocoena phocoena*, in Funka Bay, Hokkaido, Japan. Marine Mammal Science 14 (2): 209-220.

Overholtz, W.J. and G.T. Waring. 1991. Diet composition of pilot whales *Globicephala* sp. and common dolphins *Delphinus delphis* in the Mid-Atlantic Bight during spring 1989. Fisheries Bulletin (Dublin) 89: 723-728.

Palka, D. 1995. Abundance estimate of the Gulf of Maine harbor porpoise. Reports of the International Whaling Commission 16 (Special Issue): 27-50.

Palka, D. 2006. Summer abundance estimates of cetaceans in US Navy operating areas. Northeast Fisheries Science Center Reference Document 06-03: 52 pp.

Palka, D., A. Read and C. Potter. 1997. Summary of knowledge of white-sided dolphins (*Lagenorhynchus acutus*) from US and Canadian Atlantic waters. Reports of the International Whaling Commission 47: 729-734.

Palka, D.L., A.J. Read, A.J. Westgate and D.W. Johnston. 1996. Summary of current knowledge of harbour porpoises in US and Canadian Atlantic waters. Report of the International Whaling Commission 46: 559-565.

Pemberton, D., B. Merdsoy, R. Gales and D. Renouf. 1994. Interaction between offshore trawlers and harp and hooded seals off Newfoundland. Biological Conservation 68: 123-127.

Perez, J.A.A. and R. Wahrlich. 2005. A bycatch assessment of the gillnet monkfish *Lophius gastrophysus* fishery off southern Brazil. Fisheries Research 72: 81-95.

Perrin, W.F. 2002. Common Dolphins. *Delphinus delphis*, *D.capensis*, and *D.tropicalis*. Pages 245-248 in W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.): Encyclopedia of Marine Mammals. Academic Press, London, UK.

Peterson, C.H., H.C. Summerson, E. Thomson, H.S. Lenihan, J. Grabowski, L. Manning, F. Micheli and G. Johnson. 2000. Synthesis of linkages between benthic and fish communities as a key to protecting essential fish habitat. Bulletin of Marine Science 66 (3): 759-774.

Piatt, J.F. and D.N. Nettleship. 1987. Incidental catch of marine birds and mammals in fishing nets off Newfoundland, Canada. Marine Pollution Bulletin 18: 344-349.

Piatt, J.F., D.N. Nettleship and W. Threlfall. 1984. Net-mortality of common murres and Atlantic puffins in Newfoundland, 1951-81. Page 196-206 In: Marine birds: their feeding ecology and commercial fisheries relationships.

D. N. Nettleship, G. A. Sanger and P. F. Springer (Ed.), Supply and Services Canada, Seattle, WA.
Pierpoint, C., S. Earl and M. Baines. 1994. Observations of harbour porpoise in West Wales, 1993. European Research on Cetaceans 8: 75-78.
Polachek, T., F.W. Wenzel and G. Early. 1995. What do stranding data say about harbor porpoises (*Phocoena phocoena*)? Reports of the International Whaling Commission 16 (Special Issue): 169-179.
Prena, J., P. Schwinghamer, T.W. Rowell, D.C. Gordon, K.D. Gilkinson, W.P. Vass and D.L. McKeown. 1999. Experimental otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland: analysis of trawl bycatch and effects on epifauna. Marine Ecology Progress Series 181: 107-124.
Rattenborg, N.C., C.J. Amlaner and S.L. Lima. 2000. Behavioral, neurophysiological and evolutionary perspectives on unihemispheric sleep. Neuroscience and Biobehavioral Reviews 24: 817-842.
Read, A.J. 1990. Reproductive seasonality in harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. Canadian Journal of Zoology 68: 284-288.
Read, A.J. 1994a. Interactions between cetaceans and gillnet and trap fisheries in the Northwest Atlantic. Reports of the International Whaling Commission 15 (Special Issue): 133-149.
Read, A.J. 1994b. Interactions between cetaceans and gillnet and trap fisheries in the northwest Atlantic. Reports of the International Whaling Commission 15 (Special Issue): 133-147.
Read, A.J. 1999. Harbour Porpoise. Pages 323-355 in S. H. Ridgway and R. Harrison (eds.): Handbook of Marine Mammals Volume 6: The Second Book of Dolphins and the Porpoises. Academic Press, London, UK.
Read, A.J. 2000. Potential mitigation measures for reducing the by-catches of small cetaceans in ASCOBANS waters. Report to ASCOBANS, 22 pp.
Read, A.J., P. Drinker and S. Northridge. 2003. By-catches of marine mammals in U.S. fisheries and a first attempt to estimate the magnitude of global marine mammal by-catch. Reports of the International Whaling Commission 55: 12 pp.
Read, A.J., P. Drinker and S. Northridge. 2006. Bycatch of marine mammals in U.S. and global fisheries. Conservation Biology 20 (1): 163-169.
Read, A.J. and D.E. Gaskin. 1988. Incidental catch of Harbour Porpoises in Bay of Fundy groundfish gill nets. Jounal of Wildlife Management 52 (3): 517-523.
Read, A.J. and D.E. Gaskin. 1990. Changes in growth and reproduction of harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 47 (11): 2158-2163.
Read, A.J. and A.A. Hohn. 1995. Life in the fast lane: the life history of harbor porpoises from the Gulf of Maine. Marine Mammal Science 11 (4): 423-440.

Read, A.J. and K.A. Tolley. 1997. Postnatal growth and allometry of harbour porpoises from the Bay of Fundy. Canadian Journal of Zoology 75 (1): 122-130.
Read, A.J. and A.J. Westgate. 1997. Monitoring the movements of harbour porpoises (*Phocoena phocoena*) with satellite telemetry. Marine Biology 130 (2): 315-322.
Recchia, C.A. and A.J. Read. 1989. Stomach contents of harbour porpoises, *Phocoena phocoena* (L.), from the Bay of Fundy. Canadian Journal of Zoology 67: 2140-2146.
Reeves, R.R., W.F. Perrin, B.L. Taylor, C.S. Baker and S.L. Mesnick. 2004. Report of the Workshop on Shortcomings of Cetacean Taxonomy in Relation to Needs of Conservation and Management. April 30-May 2, 2004, La Jolla, California. NOAA-NMFS-SWFSC-363: 1-94 pp.
Reeves, R.R., C. Smeenk, R.L. Brownell Jr. and C.C. Kinze. 1999a. Atlantic White-sided dolphin *Lagenorhynchus acutus* (Gray, 1828). Pages 31-56 in S. H. Ridgway and R. Harrison (eds.): Handbook of Marine Mammals Volume 6: The Second Book of Dolphins and the Porpoises. Academic Press, London, UK.
Reeves, R.R., C. Smeenk, C.C. Kinze, R.L. Brownell Jr. and J. Lien. 1999b. White-beaked Dolphin *Lagenorhynchus albirostris* Gray, 1846. Pages 1-30 in S.H. Ridgway and R. Harrison (eds.): Handbook of Marine Mammals Volume 6: The Second Book of Dolphins and the Porpoises. Academic Press, London, UK.
Reeves, R.R., B.D. Smith, E.A. Crespo and G. Notarbartolo di Sciara. 2003. Dolphins, Whales and Porpoises: 2002–2010 Conservation Action Plan for the World's Cetaceans. Cetacean Specialist Group. IUCN, ix + 139 pp. .
Reyes, J.C. and J.A. Oporto. 1994. Gillnet Fisheries and Cetaceans in the Southeast Pacific. Report of the International Whaling Commission 15 (Special Issue): 467-474.
Rice, D. 1998. Marine mammals of the world: systematics and distribution, Special Publication Number 4, The Society for Marine Mammalogy,, Lawrence, KS.
Richardson, S.F. 1992. Growth and reproduction of the harbour porpoise, *Phocoena phocoena* (L.), from eastern Newfoundland. Department of Biology, Memorial University of Newfoundland, St. John's, NL, Canada: 102 pp.
Ridgway, S.H. 2002. Asymmetry and symmetry in brain waves from dolphin left and right hemispheres: Some observations after anesthesia, during quiescent hanging behavior, and during visual obstruction. Brain, Behavior and Evolution 60 (5): 265-274.
Rogan, E., J.R. Baker, P.D. Jepson, S. Berrow and O. Kiely. 1997. A mass stranding of white-sided dolphins (*Lagenorhynchus acutus*) in Ireland: biological and pathological studies. Journal of Zoology (London) 242: 217-227.

Rose, G.A. 2003. Fisheries resources and science in Newfoundland and Labrador: An independent assessment. Royal Commission on Renewing and Strengthening Our Place in Canada, 84 pp.
Rose, G.A. and D.W. Kulka. 1999. Hyperaggregation of fish and fisheries: how catch-per-unit-effort increased as the northern cod (*Gadus morhua*) declined. Canadian Journal of Fisheries and Aquatic Sciences 56 (Supplement 1): 118-127.
Rose, G.A. and R.L. O'Driscoll. 2002. Capelin are good for cod: can the northern stock rebuild without them? ICES Journal of Marine Science 59 (5): 1018-1026.
Rosel, P.E., A.E. Dizon and M.G. Haygood. 1995. Variability of the mitochondrial control region in populations of the harbour porpoise, *Phocoena phocoena*, on interoceanic and regional scales. Canadian Journal of Fisheries and Aquatic Sciences 52 (6): 1210-1219.
Rosel, P.E., A.E. Dizon and J.E. Heyning. 1994. Genetic analysis of sympatric morphotypes of common dolphins (genus *Delphinus*). Marine Biology 119 (2): 159-167.
Rosel, P.E., S.C. France, J.Y. Wang and T.D. Kocher. 1999a. Genetic structure of harbour porpoise *Phocoena phocoena* populations in the northwest Atlantic based on mitochondrial and nuclear markers. Molecular Ecology 8: S41-S54.
Rosel, P.E., R. Tiedemann and M. Walton. 1999b. Genetic evidence for limited trans-Atlantic movements of the harbor porpoise *Phocoena phocoena*. Marine Biology 133 (4): 583-591.
Rossbach, K.A. and D.L. Herzing. 1997. Underwater observations of benthic-feeding bottlenose dolphins (*Tursiops truncatus*) near Grand Bahama Island, Bahamas. Marine Mammal Science 13 (3): 498-504.
Rossbach, K.A. and D.L. Herzing. 1999. Inshore and offshore bottlenose dolphin (*Tursiops truncatus*) communities distinguished by association patterns near Grand Bahama Island, Bahamas. Canadian Journal of Zoology 77 (4): 581-592.
Rossman, M.C. 2000. Effectiveness of time/area closures and acoustic deterrents as harbor porpoise bycatch reduction strategies off the northeast coast of the United States. Paper SC/52/SM23 submitted to the International Whaling Commission Scientific Committee: 9 pp.
Rossman, M.C. and R.L. Merrick. 1999. Harbor porpoise bycatch in the Northeast multispecies sink gillnet fishery and the mid-Atlantic coastal gillnet fishery in 1998 and during January-May 1999. National Marine Fisheries Service, Northeast Fisheries Science Center Reference Document, 99-17: iv + 36 pp.
Ryan, S. 1971. The Newfoundland cod fishery in the nineteenth century. Ph.D. thesis, Department of History, Memorial University of Newfoundland, St. John's, NL, Canada: 328 pp.

Schrank, W.E. 1996. Origins of Atlantic Canada's fishing crisis. Pages 27-44 in D.V. Gordon and G.R. Munro (eds.): Fisheries and uncertainty. A precautionary approach to resource management. University of Calgary Press, Calgary, AB, Canada.

Scott, W.B. and M.G. Scott. 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 219: 731.

Selzer, L.A. and P.M. Payne. 1988. The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeastern United States. Marine Mammal Science 4: 141-153.

Sergeant, D.E., A.W. Mansfield and B. Beck. 1970. Inshore records of cetacea for eastern Canada. Journal of the Fisheries Research Board of Canada 27: 1903-1915.

Sergeant, D.E., D.J. St.Aubin and J.R. Geraci. 1980. Life history and Northwest Atlantic status of the Atlantic white-sided dolphin, *Lagenorhynchus acutus*. Cetology 37: 1-12.

Shortall, D. 1973. Environmental perception in two local fisheries: A case study from Eastern Newfoundland. M.Sc. thesis, Memorial University of Newfoundland, St. John's, NL, Canada: 191 pp.

Silber, G.K., M.W. Newcomer, P.C. Silber, H. Perez-Cortes and G.M. Ellis. 1994. Cetaceans of the northern Gulf of California: Distribution, occurrence, and relative abundance. Marine Mammal Science 10 (3): 283-298.

Silvani, L., M. Gazo and A. Aguilar. 1999. Spanish driftnet fishing and incidental catches in the western Mediterranean. Biological Conservation 90 (1): 79-85.

Sinclair, A.F. and S.A. Murawski. 1997. Why have groundfish stocks declined? Pages 71-94 in J. Boreman, B.S. Nakashima, J.A.Wilson, and R.L. Kendall (eds.): Northwest Atlantic Groundfish: Perspectives on a Fishery Collapse. American Fisheries Society, Bethesda, MD, USA.

Smith, R.J. and A.J. Read. 1992. Consumption of euphausiids by harbour porpoise (*Phocoena phocoena*) calves in the Bay of Fundy. Canadian Journal of Zoology 70: 1629-1632.

Sonntag, R.P., H. Benke, A.R. Hiby, R. Lick and R. Adelung. 1999. Identification of the first harbour porpoise (*Phocoena phocoena*) calving ground in the North Sea. Journal of Sea Research 41: 225-232.

St. Aubin, D.J. and J.R. Geraci. 1979. Strandings: a rare look into the biology of the Atlantic white-sided dolphin *Lagenorhynchus acutus*. Pages 190-206 in J.R Geraci and D.J. St. Aubin (eds.): Biology of marine mammals: Insights through strandings. U.S. Marine Mammal Commission Report No. MMC-77113, Washington D.C., USA.

Stenson, G.B. 2003. Harbour porpoise in the North Atlantic: Abundance, removals, and sustainability of removals. NAMMCO Scientific Publications 5: 271-302.

Stenson, G.B., M.O. Hammill and J.W. Lawson. 1997a. Predation by harp seals in Atlantic Canada: preliminary consumption estimates for Arctic cod, capelin, and Atlantic cod. Journal of Northwest Atlantic Fisheries Science 22: 137-154.

Stenson, G.B. and D.G. Reddin. 1997. Incidental catches of small cetaceans in experimental salmon driftnets in the Northwest Atlantic. Poster presented at ICES Annual Science Conference, Baltimore, MD, U.S.A: CM 1997/Q:04.

Stenson, G.B., B. Sjare, M.O. Hammill and J.W. Lawson. 1997b. Estimating consumption of Atlantic cod by harp and hooded seals in the northwest Atlantic. Poster presented at the Canadian Conference for Fisheries Research, Ottawa, ON, Canada.

Stevenson, S.C. and J.W. Baird. 1988. The fishery for lumpfish (*Cyclopterus lumpus*) in Newfoundland waters. Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences 1595: 26 pp.

Teilmann, J., J. Tougaard, L.A. Miller, T. Kirketerp, K. Hansen and S. Brando. 2006. Reactions of captive harbour porpoises (*Phocoena phocoena*) to pinger-like sounds. Marine Mammal Science 22 (2): 240-260.

Templeman, W. 1966. Marine resources of Newfoundland. Fisheries Research Board of Canada Bulletin 154: 170.

Thrush, S.F., J.E. Hewitt, V.J. Cummings, P.K. Dayton, M. Cryer, S.J. Turner, G.A. Funnell, R.G. Budd, C.J. Milburn and M.R. Wilkinson. 1998. Disturbance of the marine benthic habitat by commercial fishing: Impacts at the scale of the fishery. Ecological Applications 8 (3): 866-879.

Tiedemann, R., J. Harder, C. Gmeiner and E. Haase. 1996. Mitochondrial DNA sequence patterns of harbour porpoises (*Phocoena phocoena*) from the North and the Baltic Sea. Zeitschrift für Säugetierkunde 61 (2): 104-111.

Tomilin, A.G. 1957. Cetacea. Mammals of the U.S.S.R. and Adjacent Countries, Vol. IX. Nauk S.S.S.R., Moscow.

Tregenza, N.J.C., S. Berrow, P.S. Hammond and R. Leaper. 1997a. Common dolphin, *Delphinus delphis* L., bycatch in bottom set gillnets in the Celtic Sea. Forty-Seventh Report of the International Whaling Commission (Covering the Forty-Seventh Financial Year 1995-1996) 47: 835-839.

Tregenza, N.J.C., S.D. Berrow, P.S. Hammond and R. Leaper. 1997b. Harbor porpoise (*Phocoena phocoena* L.) by-catch in set gillnets in the Celtic sea. ICES Journal of Marine Science 54: 896-904.

Tregenza, N.J.C. and A. Collet. 1998. Common dolphin *Delphinus delphis* bycatch in pelagic trawl and other fisheries in the North East Atlantic. Reports of the International Whaling Commission 48: 453-459.

Trippel, E.A., M.B. Strong, J.M. Terhune and J.D. Conway. 1999. Mitigation of harbour porpoise (*Phocoena phocoena*) by-catch in the gillnet fishery in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 56 (1): 113-123.

Tudela, S. 2004. Ecosystem effects of fishing in the Mediterranean: An analysis of the major threats of fishing gear and practices to biodiversity and marine habitats. FAO General Fisheries Commission for the Mediterranean Study #74: 58 pp.

Van Bree, P.J.H., D.E. Sergeant and W. Hoek. 1977. A harbour porpoise, *Phocoena phocoena* (Linnaeus, 1758), from the Mackenzie River delta, Northwest Territories, Canada. Beaufortia 26 (333): 99-105.

Van Waerebeek, K., M. Van Bressem, F. Felix, J. Alfaro-Shigueto, A. Garcia-Godos, L. Chavez-Lisambart, K. Onton, D. Montes and R. Bello. 1997. Mortality of dolphins and porpoises in coastal fisheries off Peru and southern Ecuador in 1994. Biological Conservation 81 (1-2): 43-49.

Víkingsson, G.A., D. Olafsdøttir and J. Sigurjønsson. 2003. Diet of harbour porpoises (*Phocoena phocoena*) in Icelandic coastal waters. NAMMCO Scientific Publications 5: 243-270.

Vinther, M. 1999. Bycatches of harbour porpoises (*Phocoena phocoena* L.) in Danish set-net fisheries. Journal of Cetacean Research and Management 1 (2): 123-135.

Vis, M.L., S.M. Carr, W.R. Bowering and W.S. Davidson. 1997. Greenland halibut (*Reinhardtius hippoglossoides*) in the North Atlantic are genetically homogeneous. Canadian Journal of Fisheries and Aquatic Sciences 54: 1813-1821.

Visser, I.N. 2000. Killer whale (*Orcinus orca*) interactions with longline fisheries in New Zealand waters. Aquatic Mammals 26 (3): 241-252.

Volgenau, L., S.D. Kraus and J. Lien. 1995. The impact of entanglements on two substocks of the western North Atlantic humpback whale (*Megaptera novaeangliae*). Canadian Journal of Zoology 73: 1689–1698.

Walsh, D., B. Sjare and G.B. Stenson. 2000. Preliminary Estimates of Harp Seal By-catch in the Newfoundland Lumpfish Fishery. Canadian Stock Assessment Secretariat Research Document 2000/078. 16 pp.

Walsh, P. 2006. Winter longline fishing in Scott Inlet/Sam Fjord, Baffin Island: Investigations into the capacity of the turbot resource to support a commercial and/or subsistence fishery. CSAR Technical Report P-194: 20 pp.

Walton, M.J. 1997. Population structure of harbour porpoises *Phocoena phocoena* in the seas around UK and adjacent waters. Proceedings of the Royal Society of London B Biological Sciences 264: 89-94.

Wang, J.Y., D.E. Gaskin and B.N. White. 1996. Mitochondrial DNA analysis of harbour porpoise, *Phocoena phocoena*, subpopulations in North American waters. Canadian Journal of Fisheries and Aquatic Sciences 53 (7): 1632-1645.

Waring, G.T., R.M. Pace, J.M. Quintal, C.P. Fairfield, K. Maze-Foley, N. Cabana, P.J. Clapham, T.V.N. Cole, G.L. Fulling, L.P. Garrison, A.A. Hohn, B.G. Maise, W.E. McFee, K.D. Mullin, D.L. Palka, P.E. Rosel, M.C. Rossman, F.W. Wenzel and A.L. Whitingham. 2003. U.S. Atlantic and Gulf of Mexico

marine mammal stock assessments - 2003. NOAA Technical Memorandum NMFSNE-182: 287 pp.
Waring, G.T., D.L. Palka, P.J. Clapham, S. Swartz, M.C. Rossman, T.V.N. Cole, L.J. Hansen, K.D. Bisack, K.D. Mullin, R.S. Wells, D.K. Odell and N.B. Barros. 1999. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments - 1999. NOAA Technical Memorandum. NMFSNE-153: 196 pp.
Wartzok, D. and D.R. Ketten. 1999. Marine mammal sensory systems. Pages 117-175 in J. E. Reynolds III and S. A. Rommel (eds.): Biology of Marine Mammals, Smithsonian Institution Press, Washington, D.C., USA.
Watling, L. and E.A. Norse. 1998. Disturbance of the seabed by mobile fishing gear: A comparison to forest clearcutting. Conservation Biology 12 (6): 1180-1197.
Westgate, A.J., A.J. Read, P. Berggren, H.N. Koopman and D.E. Gaskin. 1995. Diving behaviour of harbour porpoises, *Phocoena phocoena*. Canadian Journal of Fisheries and Aquatic Sciences 52: 1064-1073.
Westgate, A.J. and K.A. Tolley. 1999. Geographical differences in organochlorine contaminants in harbour porpoises *Phocoena phocoena* from the western North Atlantic. Marine Ecology Progress Series 177: 255-268.
Whitehead, H. and C. Glass. 1985. The significance of the Southeast Shoal of the Grand Bank to humpback whales and other cetacean species. Canadian Journal of Zoology 63 (11): 2617-2625.
Wickens, P. 1995. A review of operational interactions between pinnipeds and fisheries. FAO Fisheries Technical Paper 346. 86 pp.
Wilson, B. and L.M. Dill. 2002. Pacific herring respond to simulated odontocete echolocation sounds. Canadian Journal of Fisheries and Aquatic Sciences 59 (3): 542-553.
Worthy, G.A.J. and E.F. Edwards. 1990. Morphometric and biochemical factors affecting heat loss in a small temperate cetacean (*Phocoena phocoena*) and a small tropical cetacean (*Stenella attenuata*). Physiological Zoology 63 (2): 432-442.
Wright, M. 2001. A fishery for modern times: the state and the industrialisation of the Newfoundland fishery, 1934-1968. Oxford University Press, Don Mills, Ontario, Canada; viii + 196 pp.
Yano, K. and M.E. Dahlheim. 1995. Killer whale, *Orcinus orca*, depredation on longline catches of bottomfish in the southeastern Bering sea and adjacent waters. Fishery Bulletin 93: 355-372.
Yurick, D.B. and D.E. Gaskin. 1987. Morphometric and meristic comparisons of skulls of harbour porpoise *Phocoena phocoena* (L.) from the North Atlantic and North Pacific. Ophelia 27 (1): 53-74.
Zollett, E.A. and A.J. Read. 2006. Depredation of catch by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery. Fishery Bulletin 104 (3): 343-349.

CHAPTER 2 - SMALL CETACEAN INCIDENTAL CATCH RESEARCH IN NEWFOUNDLAND AND LABRADOR

2.1 - Introduction

Substantial numbers of small cetaceans, most of which were harbour porpoises, have been reported entangled in various fisheries in parts of the northwest Atlantic over the last several decades (e.g. Lien 1987; Read and Gaskin 1988; Jefferson and Curry 1994; Read 1994b; Donovan and Bjørge 1995; Palka *et al.* 1996; Stenson and Reddin 1997; COSEWIC 2003; Read *et al.* 2003; Stenson 2003; Waring *et al.* 2003). The continued occurrence of these incidental catches in gillnet fisheries in Atlantic Canadian and U.S. waters have led to the responsible management agencies taking action to assess and, where possible, minimize the impact of this anthropogenic mortality. Only limited data are available for Newfoundland and Labrador waters, but there have been repeated indications of potentially significant levels of incidental catches. The widespread reduction in nearshore fishing effort in Newfoundland and Labrador and other parts of Atlantic Canada, following the commercial closure of various demersal fish stocks in the early 1990s, is suspected to have reduced the frequency of incidental catch of harbour porpoise (DFO 2001). However, this assumption has yet to be accurately tested.

The first section of this chapter reviews methods used to assess incidental catch of small cetaceans, with a particular focus on Newfoundland and Labrador. The remainder of the chapter describes the various studies that have previously reported incidental catches of small cetaceans in Newfoundland and Labrador. Additional information is presented on small cetacean incidental catch in adjacent northwest Atlantic waters.

2.2 - Methods of Assessing Incidental Catch

The study of incidental catch of cetaceans in commercial fisheries has become more prevalent in recent decades, due to an increased understanding of the potential threats caused by catches in fishing gear to cetacean populations. However, there is no consensus on the most efficient means to monitor and manage this incidental catch. Any successful data collection scheme must acknowledge potential changes in the commercial fishing industry, including technological advances, rapid changes in gear types, geographical and/or temporal shifts in fishing effort, combined with possible changes in environmental parameters that may affect the marine ecosystem as a whole. Fisheries management organizations in some nations have a legislative mandate to observe and manage marine mammal incidental catches, but this is not the norm in many parts of the world, including Canada.

Various methods have been developed to monitor and estimate rates of incidental catches of small cetaceans in commercial fisheries, including observer programs, strandings surveys, reporting schemes, carcass salvage schemes, interviews and logbook analysis (Northridge 1996; Spencer *et al.* 1999). All of these methods have potential advantages and drawbacks, depending on local circumstances. In any study collecting data on incidental catch of marine mammals, a compromise must be reached between programme cost and data accuracy. Various methods may be used in tandem, to make use of as many sources of information as possible. Methods described in this chapter are summarized in Table 2.1.

2.2.1 - Observer Programs

A dedicated marine mammal observer programme is considered one of the most accurate, if expensive, methods to monitor incidental catch of marine mammals (e.g. Waring *et al.* 1990; Edwards and Perrin 1993; Northridge 1996; Trippel *et al.* 1996; Couperus 1997; Tregenza *et al.* 1997a; 1997b; Morizur *et al.* 1999; Spencer *et al.* 1999; DFO 2001; Lesage *et al.* 2004). Ideally, independent, trained observers 1) should be distributed through the commercial fishery based either on overall fishing effort or on the likelihood of incidental catch in specific fisheries; 2) should focus solely on monitoring marine mammal bycatch and associated fisheries data; and 3) should be debriefed upon completion of each deployment to clarify any uncertainties (Northridge 1996; Babcock *et al.* 2003).

In practice, it may be impossible to meet some or all of these conditions. The main problem with observer programs is the violation of the assumption that all observations are representative of the fishery as a whole. Observers are often unable to study a randomly selected and representative subsample of fishing activity in all hauls, on all types of vessels, in all fishing areas. This can be caused by lack of space for observers aboard small vessels, logistical difficulties of placing observers on vessels in remote rural areas, and opposition from some fishers. The percentage of fishing activity that is actually monitored may vary from 100% in some fisheries such as the Eastern Tropical Pacific tuna fishery, to less than 1% in many small-boat fisheries (Northridge 1996; Babcock *et al.* 2003). A coverage level of 50% of total fishing effort may be required to achieve reasonable coverage of incidental catches of species that are only rarely encountered, such as marine mammals (Babcock *et al.* 2003). This also assumes that fishers are supportive of such an observation scheme.

An independent marine mammal incidental catch observer programme can be expensive. Consequently, monitoring of incidental catch of marine mammals has often been incorporated into existing fisheries monitoring programs (Northridge 1996; Spencer *et al.* 1999). In practice, this means that most observations of marine mammal incidental catch are made while collecting data on other species, which likely leads to underreporting of marine mammal catch (Northridge 1996; Richter 1998; Hood 2001). Regardless of the degree of coverage, it is impossible for Fishery Observers to record all incidental capture events taking place in fishing operations. Some animals may die in fishing gear such as gillnets but may subsequently fall out or otherwise get disentangled by wave action or by net movement as they are being hauled in (Tregenza 1994; Bravington and Bisack 1996). Nighttime fishing activity may also reduce observers' chances of detecting animals. In addition, observers may not be able to sample the catch of every haul, especially when gear is not taken out of the water between sets, as may be the case in industrial fisheries using trawls equipped with fish pumps (personal observation).

Another possible source of uncertainty includes "observer bias", where the presence of an observer on board the vessel changes the way the crew decides to deploy their fishing gear (Babcock *et al.* 2003; Lesage *et al.* 2004). Other sources of uncertainty include accidentally combining distinct sectors of the fishery to achieve a larger sample size during data analysis (when fishing sectors that differ in gear use, fishing methods etc. are not recognized as such), and inaccurate recording by observers due to lack of training, friendship with the crew, intimidation, or bribery (Babcock *et al.* 2003).

Notwithstanding their potential impact on populations, incidental catches of small cetaceans and pinnipeds are typically rare events in the day-to-day experience of most fishers and Fishery Observers. The vast majority of catches will have no incidental catch associated with them, but a small fraction may have large numbers of animals being captured at the same time. This clumped distribution can severely influence the final estimate of incidental catch. A possible solution is increasing the observer coverage, but this may not be possible or practical. Resampling methodologies may be employed to redistribute incidental catch rates according to a normal distribution (Blank *et al.* 2001).

The Department of Fisheries and Oceans has maintained a Fishery Observer programme in Newfoundland and Labrador since 1980 (see Chapter 4). The observers record the exact geographical fishing location, depth, duration of haul, number and length of nets, and exact amounts of catch and discards of all species (Kulka *et al.* 2000). Observers also record incidental catches of marine mammals and other types of marine megafauna such as sharks, marine turtles, and seabirds. This is not considered to be the observers' main activity, and data collected in this manner may therefore vary between years, depending on the emphasis put on collecting this information. In addition, data collection may be affected by other types of bias, as described above. Details of the dataset generated through this programme will be discussed in Chapter 4.

2.2.2 - Strandings Surveys

The study of stranded small cetaceans offers a way to collect basic biological information on small cetaceans, supplement data on potential fluctuations in the interactions with commercial fisheries, and even to initially identify that a problem involving incidental catch of small cetaceans actually exists (Cox *et al.* 1998). However, this method can only provide an absolute minimum estimate of the impact of incidental catches, as the vast majority of incidentally captured small cetaceans that are removed from fishing gear at sea are unlikely to end up on beaches and become accessible to stranding surveys (Cox *et al.* 1998; Tregenza and Collet 1998). Even when a carcass is discovered, logistical difficulties or ignorance may mean the event is never reported, and inaccessibility of the stranding location may hamper subsequent data collection. It is often impossible to conclusively establish cause of death from a stranded cetacean carcass, and this uncertainty is one of the major objections against using strandings surveys as the main source of incidental catch information. In addition, it is often unclear if stranded animals represent an unbiased subset of the population, due to possible spatio-temporal age and sex segregation among animals (ECS 1996; Cox *et al.* 1998).

The large, often sparsely populated coastline of Newfoundland and Labrador presents significant challenges in terms of reporting and collecting stranded cetaceans. The responsibility for gathering this information is shared by DFO and the Whale Release and Stranding Group, both based in the greater St. John's metropolitan area. Repeated delays in reporting of stranding events to these authorities have resulted in loss of scientific sampling opportunities, and public awareness needs to be strengthened to increase the number of timely stranding reports, especially from isolated areas.

2.2.3 - Reporting Schemes

In some areas, fishers have been asked to voluntarily report any entanglements of marine mammals to the relevant authorities (Northridge 1996). In other jurisdictions, it is a legal requirement to report such entanglements (as in the United States under the Marine Mammal Protection Act; NMFS 1997). Voluntary reporting schemes generally do not provide detailed information, since there is no motivation for most fishers to report catches, nor is there a reliable measure of concurrent fishing effort (Berggren 1994; Northridge 1996). A mandatory reporting scheme can be unpopular with fishers, since it adds to the administration they need to maintain. It does have the potential to provide important data on incidental catches, but enforcement may be a problem (Northridge 1996).

Neither mandatory nor voluntary reporting systems have been used in any Newfoundland and Labrador fishery. No federal legislation currently exists to mandate a reporting scheme for fishers, and it is unlikely that this will appear soon. With fishers being so widely distributed in this province, it appears unlikely that such a scheme would be practical in the Newfoundland context.

2.2.4 - Carcass Salvage Schemes

Some research programs have contacted fishers to request that they bring ashore any marine mammal carcasses that are found entangled in their fishing gear, for the purposes of correct identification and further scientific data collection, including morphometrics and tissue samples (Crespo *et al.* 1994; Kinze 1994; Lien *et al.* 1994; Lockyer *et al.* 2001). Carcass salvage schemes are unlikely to provide more than a minimum estimate of incidental catch (Northridge 1996; Spencer *et al.* 1999). Such a scheme can be expensive, particularly where fishers are widely distributed, requiring potentially significant costs for storage and transportation of carcasses (Table 2.1). Fishers may object to storing carcasses due to space limitations on board their vessels, excessive time spent handling the carcass, and/or a sense of self-implication by bringing marine mammal catches (and, in some areas, the consumption of marine mammals) to the attention of outsiders (Table 2.1). These factors may limit or negate the effectiveness of carcass recovery schemes (Crespo *et al.* 1994; IWC 1994; Lescrauwaet and Gibbons 1994; Reyes and Oporto 1994; Reeves *et al.* 2003). Providing fishers with financial compensation (for storage costs etc.) may improve the level of cooperation; however, compensation should not entice fishers to actively target marine mammals (Lien *et al.* 1994; Spencer *et al.* 1999).

In Canada, it is illegal under the Fisheries Act for fishers to bring marine mammals ashore unless specifically authorized to do so by DFO. The Marine Mammal Section of DFO has licensed several fishers around the province to bring in any seal or small cetacean they find entangled in their fishing gear, under the auspices of the locally administrated Marine Mammal Bycatch Collector programme (Chapter 3). These permits are updated yearly and fishers receive a payment of C$25.00 per animal at the end of the year to compensate them for costs incurred while handling, storing or transporting the carcass.

Until recently, DFO technicians periodically travelled around rural Newfoundland to collect locally stored carcasses for detailed necropsies in St. John's. In 2006, due to financial and logistic constraints within the Department, the scope of this programme was limited with a request to fishers to no longer retain carcasses, but collect some samples (e.g. the lower jaw) at sea before discarding the remains. No samples have been received to date (W. Penney, DFO-NL, pers. comm.).

2.2.5 - Interviews

Various types of interviewing techniques have been used by researchers to obtain information from fishers on incidental catch of a variety of species, including marine mammals. These are generally considered to be low-cost alternatives to dedicated observer programs (Spencer *et al.* 1999). Examples include mailed questionnaires, phone interviews, and "dockside" face-to-face interviews (Fontaine *et al.* 1994; Lien *et al.* 1994). Care must be taken to contact a representative subsample of fishers, though this requirement may be difficult to fulfil in some situations. Results may also be affected by fishers' inability or unwillingness to recall incidental capture events, especially when discussing historical catches (Lien *et al.* 1994). Care must be taken when using estimates volunteered by fishers, as they may have reason to underestimate incidental catch levels. An initial vetting process may limit the subsample of fishers to individuals more motivated to provide accurate information, but even in these cases, repeated checks may be necessary to develop a pool of fishers experienced in data collection. Identification of small cetaceans is often difficult due to lack of shared nomenclature between fishers and interviewers. Often, interviewers must try to determine which species of small cetacean is actually meant in fishers' reports through detailed follow-up questions. Fishers have also been shown to estimate incidental catches in a non-linear fashion, with counts running '1-2-3-4-5-dozens-hundreds-thousands' (Lien *et al.* 1989).

Mailed questionnaires, where fishers are requested to report information on fishing effort and incidental catch, require the least effort from the researcher, but can be costly if many questionnaires are mailed out over long distances. Also, the noncommittal nature of this interview type often results in low returns, since only a subset of fishers (often those already interested in the issue) are likely to take the time to complete the questionnaire (Lien 1980; Fontaine *et al.* 1994). These time requirements may also cause seasonally fluctuating return rates, as fishers will be more likely to fill out such questionnaires when they are less busy (Spencer *et al.* 1999). However, including a small financial reward (the equivalent of C$1) in the envelope has been shown to increase the return rates (J. Lien, MUN, pers. comm.).

Telephone interviews, in which fishers are asked a series of questions on fishing effort and incidental catch by trained interviewers, may be more useful when collecting incidental catch data, because interviewers can ask directed questions. In some cases, mailed interviews may be followed by a telephone interview to clarify written statements. Lien *et al.* (1994) reported fishers to be generally willing to provide information through phone interviews, but that estimates given by fishers were influenced by factors such as the gender of the interviewer, and their own previous fishing experience.

Dockside face-to-face interviews may provide relatively reliable results, although, as with telephone interviews, care must be taken to avoid bias by solely obtaining interviews of fishers who are readily available to the interviewer due to their nearshore fishing practices (Lien *et al.* 1994). Lien *et al.* (1994) reported that a long-standing relationship between interviewers and the fishers resulted in the most reliable estimates of incidental catch of marine mammals. Conducting the interview in the presence of crew or colleagues of the interviewed fisher often resulted in reinforcement or correction of their incidental catch estimates (Lien *et al.* 1994). It is then also easier to determine which species of marine mammals are caught by using guidebooks or other media. However, in other areas where a less trusting relationship might exist between fisher and interviewer, fishers may be less willing to conduct interviews that they perceive as providing potentially incriminating evidence of incidental catches of marine mammals in their fishing gear (Northridge 1996).

One downside of dockside face-to-face interviews is the amount of logistical and financial resources required for interviewers to physically meet all the fishers in their sample. The desired relationship of trust between researchers and fishers needs several years to develop, making this method less practical for short-term research. Finally, the results may vary from year to year, even for the same fisher. This variation may be caused by changes in the distribution of marine mammals as well as fish species, and economical or management changes to fisheries in the area.

Mailed questionnaires, telephone and face-to-face interview methodologies have all been used in Newfoundland and Labrador during the last 25 years (Lien 1980, 1989, 1994; Lien *et al.* 1994). Based on these experiences, face-to-face interviews are the most desirable means of gathering information, followed by telephone interviews (Table 2.1). In recent years, DFO technicians have conducted face-to-face interviews with fishers who collect fishing effort data under the Marine Mammal Bycatch Collector programme (Chapter 3).

2.2.6 - Logbook Analysis

In several jurisdictions, fishers have been asked to maintain logbooks of their fishing effort, while recording incidental catch of species such as small cetaceans, seals or seabirds (Spencer *et al.* 1999). In some areas (e.g. the U.S.), this is a mandatory requirement, but elsewhere a subsample of fishers may be requested to participate in a voluntary data collection scheme (Northridge 1996). These schemes can supplement dedicated observer programs, if a sufficiently large subsample of fishers agrees to supply data such as fishing effort, amount of gear used, amount of time the gear remained in the water, landed catch data, and any records of incidental catch of the species of interest.

If sufficient numbers of fishers are willing to participate, significant quantities of data can be collected, although several types of error may be inadvertently introduced (Table 2.1). Care should be taken that fishers supplying data are widely dispersed to prevent geographical clumping, although this depends heavily on local conditions and may be difficult to achieve. Consistency and reliability of data are common problems; meetings between researchers and fishers may be needed to clarify what data need to be collected. These meetings may help establish a long-term relationship of trust between the fisher and the researcher, which can enhance data quality (Table 2.1). Researchers have commented on the relative lack of cooperation from fishers who were asked to maintain a logbook, despite the offer of payment for returned logbooks that were correctly filled out (Polachek 1989; Lien *et al.* 1994; Read 1994). This may be caused by the feeling among fishers that they already have enough administration (Spencer *et al.* 1999).

The Marine Mammal Section of DFO-NL has maintained a Bycatch Collector programme among nearshore fishers across the island of Newfoundland for the past 15 years. Fishers participating in this programme report detailed information on commercial gillnet fishing effort, landed catch, and incidental catches. This dataset is discussed in Chapter 3.

2.3 - Historical Reports of Incidental Catches of Small Cetaceans in Newfoundland and Labrador Waters

A number of reports and estimates of incidental catches of small cetaceans in the waters around Newfoundland and Labrador have been published over the last 27 years (Lien 1979, 1980, 1983, 1987, 1989; Lien and Aldrich 1982; Lien *et al.* 1984, 1986, 1987, 1988; 1989, 1993, 1994a, 1994b, 2001; Alling and Whitehead 1987; Piatt and Nettleship 1987; Richardson 1992; Stenson and Reddin 1997; DFO 2001; Hood 2001). Most of these reports involve harbour porpoises. Incidental capture of white-beaked and Atlantic white-sided dolphins in Atlantic Canadian waters appear to occur less frequently, although captures are likely to be under-reported for these species as well. Common dolphins have only rarely been reported as incidental catches in Atlantic Canadian waters, apparently due to their limited seasonal and geographical distribution in the area.

However, many published reports only describe small numbers of incidental capture events of harbour porpoise or other small cetaceans in nearshore fisheries, and these data were often not collected systematically. Many of these instances were recorded in the annual reports of the Whale Entrapment Programme, operated by Memorial University of Newfoundland, the federal Department of Fisheries and Oceans, and the provincial Department of

Fisheries of Newfoundland and Labrador. These reports only represent a minimal indication of incidental catch of small cetaceans, since no concerted efforts were made to collect data. Rather, reports were collected during the course of day-to-day work with fishers who contacted the Programme with requests for assistance with large whale entanglements. Porpoises were most often reported caught in gillnets set for cod, although some captures in salmon gillnets and codtraps were reported (e.g. Lien *et al.* 1985, 1986, 1988). In most cases, no official fishing effort data were available for extrapolation of incidental catch rates to the entire fishery. It was suspected that fishers did not report most incidental captures of small cetaceans such as harbour porpoise to the Whale Entrapment Programme, because these entanglements typically did not cause significant damage to fishing gear, animals could fall out the net unobserved, and additional assistance to remove entangled animals from the net was not required. In addition, incidentally caught porpoises were historically consumed in some areas, further reducing the likelihood of the capture being reported (J. Lien, pers. comm.). Fishers may also have felt that reporting incidental catches of small cetaceans was not in their best economic interest.

Few incidental catch estimates have been calculated for small cetaceans in this province. Lien (1980) reported incidental catch estimates for harbour porpoise for the entire province that ranged from approximately 1,800 animals (using number of porpoises per crew) to over 25,000 animals (using number of porpoises caught per net). Based on limited data from the Entrapment Assistance and Stranding Programme, Lien (1983) derived a harbour porpoise incidental catch estimate of approximately 1,800 animals a year throughout the province, with a possible maximum of 3,000 animals per year (see also Lien (1989)). This estimate was based on landed catch as a measure of fishing effort. Piatt and Nettleship (1987) reported on incidental catches of harbour porpoise during the 1981-1984 fishing seasons in the vicinity of four major seabird colonies along the eastern coast of Newfoundland, based on catch per unit effort data (net-days) from logbooks filled out by selected fishers. An average annual catch of 140 harbour porpoises (varying annually between 112-168) was reported, leading to an estimated catch of 558 animals in this area of the eastern Newfoundland coast for the total four-year study period. Small numbers of unidentified dolphins were also captured. These data were not extrapolated to the fisheries in other parts of Newfoundland and Labrador due to a lack of coverage. Alling and Whitehead (1987) estimated that catches of small cetaceans (mostly white-beaked dolphins) along the entire Labrador coast could have been as high as 320 animals per year.

At the 2001 International Harbour Porpoise Workshop, sponsored by DFO, the current state of knowledge on harbour porpoise in Atlantic Canada was reviewed (DFO 2001). Estimating incidental mortality in fisheries in waters around Newfoundland, Labrador and the Gulf of St. Lawrence was identified as a high priority. At this meeting, several harbour porpoise incidental catch estimates were provided that had not previously been published (Lien 2001). Results from a 1980 logbook survey indicated catches of 1,368 harbour porpoises (based on percentage of fishers in the subsample who caught harbour porpoise) or 2,242 harbour porpoises (based on landed catch), when extrapolated to the entire fishery. A telephone survey in 1990 resulted in a new incidental catch estimate of 1,931 harbour porpoise in 1989, based on rates of porpoise capture per fishing enterprise (see also Lien *et al.* 1994b). A 1990 logbook survey of a small subsample of fishers yielded incidental catch estimates between 2,852-4,416 harbour porpoises, based on animals caught per enterprise. Finally, data from a 1992 telephone survey among a subsample of Newfoundland fishers on incidental catch of harbour porpoise in Newfoundland and Labrador gillnet fisheries indicated an estimated total annual catch of 2,283 animals in 1992 (DFO 2001). This estimate was based on the percentage of fishers in the subsample reporting incidental catch of porpoise. None of these estimates were linked to fishing effort.

2.4 - Historical reports of incidental catches of small cetaceans in adjacent northwest Atlantic waters

2.4 1 - The Gulf of Maine/Bay of Fundy

Most harbour porpoise research in the northwest Atlantic to date has been conducted on the population in the Gulf of Maine/Bay of Fundy area, including research on interactions with fisheries, as well as studies on aspects of biology such as morphometrics, diet, growth, reproduction and distribution (e.g. Gaskin *et al.* 1985; Read and Gaskin 1988, 1990; Woodley and Read 1991; Read 1994a; Brodie 1995; Palka 1995; Read and Hohn 1995; Westgate *et al.* 1995; Kraus *et al.* 1997; Read and Westgate 1997; Richter 1998; Trippel *et al.* 1999; Cox *et al.* 2001; Hood 2001; Börjesson and Read 2003; Neimanis *et al.* 2004; Trippel and Shepherd 2004).

For the period 1989-1993, average total incidental capture of porpoises in the Gulf of Maine/Bay of Fundy area was estimated to be approximately 1,876 animals per year (Blaylock *et al.* 1995; Waring *et al.* 2003). However, an overall reduction in fishing effort, together with a series of conservation initiatives aimed at conserving both harbour porpoise and various fish species, has led to a significant reduction in incidental catch of harbour porpoise in the Gulf of Maine/Bay of Fundy region (NMFS 1998; Richter 1998; Hood 2001; Waring *et al.*

2003; Trippel and Shepherd 2004). Recent incidental captures are estimated at approximately 150 animals per year including both Canadian and American fisheries. This level of anthropogenic mortality is not considered to be an immediate risk to this population (Waring *et al.* 2003).

Other small cetaceans in the Gulf of Maine/Bay of Fundy area do not appear to get entangled in fishing gear as often as harbour porpoises. For 1990-1995, the estimated average annual bycatch in U.S. fisheries in the Gulf of Maine/Bay of Fundy area was 181 animals, with most animals taken in bottom-set gillnets and pelagic trawls (Palka *et al.* 1997). A more recent incidental catch estimate of Atlantic white-sided dolphins is of 102 animals/year in the period 1997-2001 in various U.S. fisheries (Waring *et al.* 2003). No information is available on incidental captures of white-beaked dolphins in this region. Small numbers of common dolphins have been reported entangled in various bottom-set gillnets and trawls (Waring *et al.* 2003).

2.4.2 - The Gulf of St. Lawrence

Only limited incidental catch data are available for the harbour porpoise population in the Gulf of St. Lawrence. Studies of harbour porpoise distribution and mortality around the Gulf of St. Lawrence were initiated by Laurin (1976). High levels of incidental catch (approximately 2,000 harbour porpoises per year) have been reported from this area during the 1980s and 1990s based on questionnaires (Fontaine *et al.* 1994). Recent estimates by Lesage *et al.* (2004) show a continued high incidental catch of harbour porpoise by the nearshore cod gillnet fishery in this area (on the order of 2,000 animals per year). Occasional incidental catches in gillnets of both white-beaked dolphin and Atlantic white-sided dolphin have been reported from the Gulf of St. Lawrence (Fontaine *et al.* 1994; Read, 1994b).

2.4.3 - West Greenland

A sizeable amount of biological data on harbour porpoise is available from western Greenland, partly because the animals there are hunted for local consumption and sampling is therefore relatively straightforward (Lockyer *et al.* 2001, 2003). Incidental catches in salmon driftnets were reported during the 1972 fishing season (Lear and Christensen 1975; Christensen and Lear 1977), but this fishery was closed in the 1980s. There have been few reports of incidental catch in recent years. Most current fishing activity in Greenland waters involves deepwater fisheries targeting Greenland halibut and northern shrimp (*Pandalus* sp.), which are thought to have a lesser chance of incidentally catching harbour porpoise. The main anthropogenic impact on harbour porpoise in western Greenland continues to be directed hunting, with average annual catches of 668 animals (Teilmann and Dietz 1998; Lockyer *et al.* 2003). This hunt is currently unregulated, leading to concerns of overexploitation (Anonymous

2006). No data on incidental catches of other species of small cetaceans are currently available.

2.5 - Conclusions

In recent decades, several methods have been developed to assess incidental catch of small cetaceans in fishing gear. There are potential difficulties to all of these methods, and often several different methodologies are combined. In Newfoundland and Labrador, the most successful methods used to date include observer programmes, directed interviews of fishers, and analysis of logbooks maintained by dedicated fishers (Table 2.1). Most studies in this region to date involve interviewing fishers about their fishing effort and associated incidental catch. A lack of reliable fishing effort data has often complicated attempts to estimate incidental catches of small cetaceans.

Incidental catch of small cetaceans, especially harbour porpoise, has been reported regularly in Newfoundland and Labrador waters for over 25 years, since data on this issue were first recorded. Incidental catches of these species have probably occurred regularly for many years, presumably since gillnets came into wide use in Newfoundland and Labrador in the 1960s. However, there has been no attempt to calculate incidental catch estimates since the introduction of the various moratoria on cod fisheries. This will be the focus of Chapter 3.

2.6 - References

Alling, A.K. and H.P. Whitehead. 1987. A preliminary study of the status of white-beaked dolphins, *Lagenorhynchus albirostris*, and other small cetaceans off the coast of Labrador. Canadian Field-Naturalist 101 (2): 131-135.

Anonymous. 1995. Harbour porpoise conservation strategy for the Bay of Fundy. Department of Fisheries and Oceans (DFO), Resource Management Branch, 12 pp.

Anonymous. 2005. Northern Cod: A failure of Canadian fisheries management. Report of the Standing Committee on Fisheries and Oceans, November 2005, Ottawa, ON, 60 pp. Available online at: http://www.parl.gc.ca/-committee/CommitteePublication.aspx?SourceId=137917.

Anonymous. 2006. State of the Living Resources in Greenland. Greenland Home Rule Office website. Last updated March 21, 2006. Available online at: http://www.nanoq.gl/English/Sustainable_use/State_of_the_-living_resources_in.aspx.

Babcock, E.A., E.K. Pikitch and C.G. Hudson. 2003. How much observer coverage is enough to accurately estimate bycatch? Oceana and Pew Institute for Ocean Science, 36 pp. Available online at: http://www.-pewtrusts.com/pdf/oceana_bycatch_110403.pdf.

Berggren, P. 1994. Bycatches of the harbour porpoise (*Phocoena phocoena*) in the Swedish Skagerrak, Kattegat and Baltic Seas; 1973-1993. Report of the International Whaling Commission 15 (Special Issue): 211-215.

Blank, S., C. Seiter and P. Bruce. 2001. Resampling stats in Excel. Version 2. Resampling Stats, Inc., Arlington, VA, USA.

Blaylock, R.A., J.W. Hain, L.J. Hansen, D.L. Palka and G.T. Waring. 1995. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments. U.S. Dep. Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, NOAA Technical Memorandum NMFS-SEFSC-363, 211 pp.

Börjesson, P. and A. Read. 2003. Variation in timing of conception between populations of the harbour porpoise (*Phocoena phocoena*). Journal of Mammalogy 84: 948-955.

Bravington, M.V. and K.D. Bisack. 1996. Estimates of harbour porpoise bycatch in the Gulf of Maine sink gillnet fishery, 1990-1993. Report of the International Whaling Commission 46: 567-574.

Brodie, P.F. 1995. The Bay of Fundy/Gulf of Maine harbour porpoise (*Phocoena phocoena*): some consideration regarding species interactions, energetics, density dependence and bycatch. Report of the International Whaling Commission 16 (Special Issue): 181-187.

Christensen, O. and W.H. Lear. 1977. Bycatches in salmon drift-nets at west Greenland in 1972. Kommissionen for Videnskabelige Undersøgelser i Grønland 205 (5): 5-37.

COSEWIC [Committee on the Status of Endangered Wildlife in Canada]. 2003. COSEWIC assessment and update status report on the harbour porpoise *Phocoena phocoena* (Northwest Atlantic population) in Canada. Committee on the Status of Endangered Wildlife in Canada. vii + 30 pp. Available online at: http://www.sararegistry.gc.ca/virtual_sara/-files/cosewic/sr_harbour_porpoise_e.pdf.

COSEWIC [Committee on the Status of Endangered Wildlife in Canada]. 2006. Harbour porpoise (northwest Atlantic population). COSEWIC Species Search. Accessed on 16/05/2006. Available online at: http://www.-cosewic.gc.ca/eng/sct1/searchdetail_e.cfm.

Couperus, A.S. 1997. Interactions between Dutch midwater trawl and Atlantic White-sided dolphins (*Lagenorhynchus acutus*) southwest of Ireland. Journal of Northwest Atlantic Fisheries Science 22: 209-218.

Cox, T.M., A.J. Read, S. Barco, J. Evans, D.P. Gannon, H.N. Koopman, W.A. McLellan, K. Murray, J. Nicolas, D.A. Pabst, C.W. Potter, W.M. Swingle, V.G. Thayer, K.M. Touhey and A.J. Westgate. 1998. Documenting the bycatch of harbor porpoises, *Phocoena phocoena*, in coastal gillnet fisheries from stranded carcasses. Fishery Bulletin 96 (4): 727-734.

Cox, T.M., A.J. Read and N.J.C. Tregenza. 2001. Will harbour porpoises (*Phocoena phocoena*) habituate to pingers? Journal of Cetacean Research and Management 3 (1): 81-86.

Crespo, E.A., J.F. Corcuera and A.L. Cazorla. 1994. Interactions between marine mammals and fisheries in some coastal fishing areas in Argentina. Report of the International Whaling Commission 15 (Special Issue): 269-281.

DFO [Dept. of Fisheries and Oceans]. 2001. Proceedings of the International Harbour Porpoise Workshop, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canadian Science Advisory Secretariat, Proceedings Series, 2001/042: 47 pp.

DFO. 2004a. Newfoundland and Labrador Region Groundfish Stock Updates. Department of Fisheries and Oceans, DFO Canadian Science Advisory Secretariat Stock Status Report, 2004/047: 1-10 pp. Available online at: www.dfo-mpo.gc.ca.

DFO [Dept. of Fisheries and Oceans]. 2004b. The northern Gulf of St. Lawrence (3Pn, 4RS) cod in 2003. Department of Fisheries and Oceans, Canadian Science Advisory Secretariat Stock Status Report, 2004/019: 1-11 pp.

DFO [Dept. of Fisheries and Oceans]. 2004c. Subdivision 3Ps Cod. Department of Fisheries and Oceans, Canadian Science Advisory Secretariat Stock Status Report, 2004/039: 15 pp.

DFO [Dept. of Fisheries and Oceans]. 2004d. Unit 2 Redfish. Canadian Scientific Advisory Secretariat Stock Status Report 2004/016: 4 pp.

Donovan, G.P. and A. Bjørge. 1995. Harbour Porpoises in the North Atlantic: edited extract from the Report of the IWC Scientific Committee, Dublin 1995. Reports of the International Whaling Commission 16 (Special Issue): 3-25.

Edwards, E.F. and C. Perrin. 1993. Effects of dolphin group type, percent coverage, and fleet size on estimates of annual dolphin mortality derived from 1987 US tuna-vessel observer data. Fish. Bull. 91 (4): 628-640.

ECS [European Cetacean Society]. 1996. Diagnosis of By-catch in Cetaceans: Proceedings of the Second European Cetacean Society workshop on cetacean pathology, Montpellier, France, 2 March 1994. European Cetacean Society Newsletter 26 (Special issue): 43 pp.

Evans, W.E. 1994. Common dolphin, White-bellied porpoise *Delphinus delphis* Linnaeus, 1758. Pages 191-224 in S.H. Ridgway and R. Harrison (eds.): Handbook of marine mammals. Volume 5, Academic Press, London, U.K.

Fontaine, P.M., C. Barrette, M.O. Hammill and M.C.S. Kingsley. 1994. Incidental catches of harbour porpoises (*Phocoena phocoena*) in the Gulf of St. Lawrence and the St. Lawrence River estuary, Québec, Canada. Reports of the International Whaling Commission15 (Special Issue): 159-163.

Gaskin, D.E. 1991. COSEWIC update status report on the harbour porpoise *Phocoena phocoena* (Northwest Atlantic population) in Canada. Committee on the Status of Endangered Wildlife in Canada, 60 pp.

Gaskin, D.E., A.J. Read, P.F. Watts and G.J.D. Smith. 1985. Population dispersal, size, and interactions of harbour porpoises in the Bay of Fundy and Gulf of Maine. Canadian Technical Report on Fisheries and Aquatic Sciences 1291: 1-28.

Hood, C.C. 2001. Incidental capture of harbour porpoise, *Phocoena phocoena*, in three gillnet fisheries of the northwest Atlantic: investigation of possible causes. Ph.D. thesis, Biopsychology, Memorial University of Newfoundland, St. John's, NL, 375 pp.

IWC [International Whaling Commission]. 1994. Report of the Workshop on Mortality of Cetaceans in Passive Fishing Nets and Traps. Reports of the International Whaling Commission 15 (Special Issue): 6-57.

Jefferson, T.A. and B.E. Curry. 1994. A global review of porpoise (Cetacea, Phocoenidae) mortality in gillnets. Biological Conservation 67 (2): 167-183.

Kinze, C.C. 1994. Incidental catches of harbour porpoises (*Phocoena phocoena*) in Danish waters, 1986-89. Report of the International Whaling Commission 15 (Special Issue): 183-188.

Kraus, S.D., A.J. Read, E. Anderson, K. Baldwin, A. Solow, T. Spradlin and J. Williamson. 1997. A field test of the use of acoustic alarms to reduce incidental mortality of harbour porpoises in gill nets. Nature 388 (6642): 525-525.

Kulka, D.W., C.M. Miri and J.R. Firth. 2000. Observer Programme Training Manual - Newfoundland Region. A Science Manual for the 2000 Observer Programme Tranining Course, St. John's, Newfoundland, Canada. Department of Fisheries and Oceans (DFO), St. John's, NL: 206 pp.

Laurin, J. 1976. Preliminary study of the distribution, hunting and incidental catch of harbour porpoise, *Phocoena phocoena* L., in the Gulf and Estuary of the St. Lawrence. FAO Scientific Consultation on Marine Mammals, Bergen, Norway. ACMRR/MM/SC/93: 14 pp.

Lear, W.H. and O. Christensen. 1975. By-catches of harbour porpoise (*Phocoena phocoena*) in salmon driftnets at West Greenland in 1972. Journal of the Fisheries Research Board of Canada 32: 1223-1228.

Lens, S. 1997. Interactions between marine mammals and deepwater trawlers in the NAFO regulatory area. ICES CM 1997/Q:8. 10 pp.

Lesage, V., J. Keays, S. Turgeon and S. Hurtubise. 2004. Incidental catches of harbour porpoises (*Phocoena phocoena*) in the gillnet fishery of the Estuary and Gulf of St. Lawrence in 2000-2002. Canadian Technical Report of Fisheries and Aquatic Sciences 2552: 37 pp.

Lescrauwaet, A.-C. and J. Gibbons. 1994. Mortality of Small Cetaceans and the Crab Bait fishery in the Magellanes area of Chile since 1980. Report of the International Whaling Commission 15 (Special Issue): 485-494.

Lien, J. 1979. Whale collisions with fishing gear in Newfoundland. A Progress Report to the Ministers Committee on Whales and Whaling. Memorial University of Newfoundland: 40 pp.

Lien, J. 1980. Whale entrapment in inshore fishing gear in Newfoundland. Final Report. Memorial University of Newfoundland, 315 pp.

Lien, J. 1983. Incidental catch of harbour porpoise (*Phocoena phocoena*) off Newfoundland and Labrador. COSEWIC Working Paper, 2 pp.

Lien, J. 1987. Incidental catches of harbour porpoise (*Phocoena phocoena*) in Newfoundland. CAFSAC Working Paper WP/87/168: 6 pp.

Lien, J. 1989. Incidental catch of harbour porpoise (*Phocoena phocoena*) in waters off Newfoundland and Labrador: some estimates based on present data and a request for further study. Workshop on harbour porpoise, St. Andrews, NB, Canada: 12 pp.

Lien, J. 1994. Entrapments of large cetaceans in passive inshore fishing gear in Newfoundland and Labrador (1979-1990). Reports of the International Whaling Commission 15 (Special Issue): 149-157.

Lien, J. 2001. Incidental bycatch of harbour porpoise in Newfoundland and Labrador-as we know it. Paper presented at the Department of Fisheries and Oceans' International Harbour Porpoise Workshop, Dartmouth, NS, Canada, 26-28 March 2001: 12 pp.

Lien, J. and D. Aldrich. 1982. Damage to inshore fishing gear in Newfoundland and Labrador by whales and sharks during 1981. CAFSAC WP/82/104, N.I.C.O.S. contribution No. 6.

Lien, J., W. Barney, W. Ledwell, S. Todd, P. Stevick, J. Huntington, R. Seton and K. Curren. 1993. Incidental entrapments of marine mammals by inshore fishing gear reported in 1992, some results of by-catch monitoring and tests of acoustic deterrents to prevent whale collisions in fishing gear. A preliminary report to the Department of Fisheries and Oceans Canada - Newfoundland Region, and the Newfoundland and Labrador Department of Fisheries.

Lien, J., W. Barney, A. Verhulst and R Seton. 1991. entrapments and strandings reported to the Entrapment Assistance Programme during 1991; And a test of "Whale Alerts" for preventing whale collisions: A preliminary report to the Department of Fisheries and Oceans and the Newfoundland and Labrador Department of Fisheries. Memorial University of Newfoundland: 26 pp.

Lien, J., K. Breeck, D. Pinsent and H. Walter. 1986. Whale and shark entrapments in inshore fishing gear during 1986: A preliminary report in Fisheries and Oceans Canada. Department of Fisheries and Oceans Canada: 33 pp.

Lien, J., L. Dix, E. Lee and H. Walters. 1984. Whale and shark entrapments in inshore fishing gear during 1984: A preliminary report in Fisheries and Oceans Canada. N.I.C.O.S. Contribution No. 79: 21 pp.

Lien, J., J.H. Dong, L. Baraff, J. Harvey and K. Chu. 1982. Whale entrapment in inshore fishing gear during 1982: a preliminary report to Fisheries and Oceans Canada, September 20, 1982. Newfoundland Institute for Cold Ocean Science; Canada. Dept. of Fisheries and Oceans. Newfoundland Region: 36 pp.

Lien, J., W. Ledwell and J. Huntington. 1989. Incidental entrapments by inshore fishing gear reported in 1989: A preliminary report to the Development Branch, Fisheries and Oceans Canada - Newfoundland region; and the Newfoundland and Labrador Department of Fisheries. Memorial University of Newfoundland: 35 pp.

Lien, J., W. Ledwell and J. Huntington. 1990. Incidental entrapments by inshore fishing gear reported in 1989: A preliminary report to the Development Branch, Fisheries and Oceans Canada - Newfoundland region; and the Newfoundland and Labrador Department of Fisheries. Memorial University of Newfoundland: 14 pp.

Lien, J., J. Huntington, W. Ledwell, and T. Huntsman. 1990. Whale entrapments in inshore fishing gear and a summary of the entrapment assistance programme in Newfoundland and Labrador during 1990. A preliminary report to the fisheries Development Branch of the Department of Fisheries and Oceans, and the Newfoundland and Labrador Department of Fisheries. Memorial University of Newfoundland: 37 pp.

Lien, J., W. Ledwell and J. Nauen. 1988. Incidental entrapments in fishing gear during 1988: a preliminary report to the Newfoundland and Labrador Department of Fisheries and Oceans, Newfoundland Region. Memorial University of Newfoundland: 27 pp.

Lien, J., D. Nelson and D.J. Hai. 2001. Status of the white-beaked dolphin, *Lagenorhynchus albirostris*, in Canada. Canadian Field-Naturalist 115 (1): 118-126.

Lien, J., J. Papineau and L. Dugan. 1987. Incidental entrapments of cetaceans, sharks and marine turtles in inshore fishing gear reported during 1987 in Newfoundland and Labrador. A preliminary report submitted to the

Department of Fisheries and Oceans and the Newfoundland and Labrador Department of Fisheries. Memorial University of Newfoundland: 44 pp.
Lien, J., D. Pittman and D. Mitchell. 1994a. Entrapments in fishing gear and strandings in Newfoundland and Labrador reported to the Entrapment Assistance Programme during 1993, and preliminary reports on the impact of acoustic deterrents on the incidental catches of Harbour Porpoise in fixed fishing gear. A report to the Department of Fisheries and Oceans and the Atlantic Fisheries Adjustment Program. Memorial University of Newfoundland: 17 pp.
Lien, J., G.B. Stenson, S. Carver and J. Chardine. 1994b. How many did you catch? The effect of methodology on bycatch reports obtained from fishermen. Reports of the International Whaling Commission 15 (Special Issue): 535-540.
Lien, J., G.B. Stenson and I. Hsun-Ni. 1989. A review of incidental entrapment of seabirds, seals and whales in inshore fishing gear in Newfoundland and Labrador: a problem for fishermen and fishing gear designers. Proceedings of the 1988 World Symposium on Fishing Gear and Fishing Vessel Design, Newfoundland and Labrador Institute of Fisheries and Marine Technology, St. John's, NF: 67-71.
Lien, J., H. Walter and C. Harvey-Clark. 1985. Whale and shark entrapments in inshore fishing gear during 1985: A preliminary report to Fisheries and Oceans Canada. N.I.C.O.S. Contribution No. 110, 22 pp.
Lockyer, C., G. Desportes, M. Amundin and D. Goodson. 2001. The tail of EPIC - Elimination of harbour Porpoise Incidental Catch. Final Report to the European Commission of Project No DG XIV 97/00006, 249.
Lockyer, C., M.P. Heide-Jørgensen, J. Jensen, C.C. Kinze and T. Buus Sørensen. 2001. Age, length, and reproductive parameters of harbour porpoises *Phocoena phocoena* (L.) from West Greenland. ICES Journal of Marine Science 58 (1): 154-162.
Lockyer, C., M.P. Heide-Jørgensen, J. Jensen and M. Walton. 2003. Life history and ecology of harbour porpoises (*Phocoena phocoena*) from West Greenland. Pages 177-194 in T. Haug, G. Desportes, G. Víkingsson and L. Witting (eds.): Harbour porpoises in the North Atlantic. NAMMCO Scientific Publications, Volume 5, Tromsø, Norway.
Morizur, Y., S.D. Berrow, N.J.C. Tregenza, A.S. Couperus and S. Pouvreau. 1999. Incidental catches of marine-mammals in pelagic trawl fisheries of the northeast Atlantic. Fisheries Research 41 (3): 297-307.
Neimanis, A.S., H.N. Koopman, A.J. Westgate, L.D. Murison and A.J. Read. 2004. Entrapment of harbour porpoises (*Phocoena phocoena*) in herring weirs in the Bay of Fundy, Canada. Journal of Cetacean Research and Management 6 (1): 7-17.
NMFS [National Marine Fisheries Service]. 1997. The Marine Mammal Protection Act of 1972 (as amended through 1997): 119 pp.

NMFS [National Marine Fisheries Service]. 1998. Taking of Marine Mammals Incidental to Commercial Fishing Operations: Harbor Porpoise Take Reduction Plan Regulations 50 CFR Part 229. Federal Register 63 (231): 27 pp.

Northridge, S. 1996. A review of marine mammal bycatch observer schemes, with recommendations for best practice. JNCC Report No.219, 42 pp.

Northridge, S. and R.J. Hofman. 1999. Marine Mammal Interactions with Fisheries. Page 99-119 In: Conservation and management of marine mammals. J.R. Twiss Jr. and R.R. Reeves (Ed.), Smithsonian Institution Press, Washington, D.C., USA.

Palka, D. 1995. Abundance estimate of the Gulf of Maine harbor porpoise. Report of the International Whaling Commission, Special Issue 16: 27-50.

Palka, D., A. Read and C. Potter. 1997. Summary of knowledge of white-sided dolphins (*Lagenorhynchus acutus*) from US and Canadian Atlantic waters. Reports of the International Whaling Commission 47: 729-734.

Palka, D.L., A.J. Read, A.J. Westgate and D.W. Johnston. 1996. Summary of current knowledge of harbour porpoises in US and Canadian Atlantic waters. Report of the International Whaling Commission 46: 559-565.

Piatt, J.F. and D.N. Nettleship. 1987. Incidental catch of marine birds and mammals in fishing nets off Newfoundland, Canada. Marine Pollution Bulletin 18: 344-349.

Polachek, T. 1989. Harbour porpoises and the gillnet fishery: incidental takes spur population studies. Oceanus 32: 63-70.

Read, A.J. 1994a. Interactions between cetaceans and gillnet and trap fisheries in the Northwest Atlantic. Reports of the International Whaling Commission 15 (Special Issue): 133-149.

Read, A.J. 1994b. Interactions between cetaceans and gillnet and trap fisheries in the northwest Atlantic. Reports of the International Whaling Commission 15 (Special Issue): 133-147.

Read, A.J., P. Drinker and S. Northridge. 2003. By-Catches Of Marine Mammals In U.S. Fisheries and a First Attempt to Estimate the Magnitude of Global Marine Mammal By-Catch. Reports of the International Whaling Commission 55: 12 pp.

Read, A.J. and D.E. Gaskin. 1988. Incidental catch of Harbour Porpoises in Bay of Fundy groundfish gill nets. Jounal of Wildlife Management 52 (3): 517-523.

Read, A.J. and D.E. Gaskin. 1990. Changes in growth and reproduction of harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 47 (11): 2158-2163.

Read, A.J. and A.A. Hohn. 1995. Life in the fast lane: the life history of harbor porpoises from the Gulf of Maine. Marine Mammal Science 11 (4): 423-440.

Read, A.J. and A.J. Westgate. 1997. Monitoring the movements of harbour porpoises (*Phocoena phocoena*) with satellite telemetry. Marine Biology 130 (2): 315-322.

Reeves, R.R., B.D. Smith, E.A. Crespo and G. Notarbartolo di Sciara. 2003. Dolphins, Whales and Porpoises: 2002–2010 Conservation Action Plan for the World's Cetaceans. Cetacean Specialist Group. IUCN, ix + 139 pp.

Reyes, J.C. and J.A. Oporto. 1994. Gillnet Fisheries and Cetaceans in the Southeast Pacific. Report of the International Whaling Commission 15 (Special Issue): 467-474.

Richardson, S.F. 1992. Growth and reproduction of the harbour porpoise, *Phocoena phocoena* (L.), from eastern Newfoundland. Department of Biology, Memorial University of Newfoundland, St. John's, NL, 102 pp.

Richter, C. 1998. Harbour porpoise and people: Strategies for bycatch reduction in ther Bay of Fundy. M.Sc. thesis, Biopsychology Programme, Memorial University of Newfoundland, St. John's, NL, x + 150 pp.

Spencer, N., B. Santos Vazquez and G.J. Pierce. 1999. Evaluation of the state of knowledge concerning by-catches of cetaceans. University of Aberdeen, UK, Aberdeen, UK: 212. Available online at: http://www.europa.eu.int/-comm/fisheries/doc_et_publ/liste_publi/studies/bycatch/contents.htm

Stenson, G.B. 2003. Harbour porpoise in the North Atlantic: Abundance, removals, and sustainability of removals. NAMMCO Scientific Publications 5: 271-302.

Stenson, G.B. and D.G. Reddin. 1997. Incidental catches of small cetaceans in experimental salmon driftnets in the Northwest Atlantic. Poster presented at ICES Annual Science Conference, Baltimore, MD, U.S.A: CM 1997/Q:04.

Teilmann, J. and R. Dietz. 1998. Status of the harbour porpoise in Greenland. Polar Biology 19: 211-220.

Tregenza, N.J.C. 1994. By-catch pathology as seen from the fishing boat. European Cetacean Society Newsletter 26 (Special issue): 10-11.

Tregenza, N.J.C., S. Berrow, P.S. Hammond and R. Leaper. 1997a. Common dolphin, *Delphinus delphis* L., bycatch in bottom set gillnets in the Celtic Sea. Forty-Seventh Report of the International Whaling Commission (Covering the Forty-Seventh Financial Year 1995-1996): 835-839.

Tregenza, N.J.C., S.D. Berrow, P.S. Hammond and R. Leaper. 1997b. Harbor porpoise (*Phocoena phocoena* L.) by-catch in set gillnets in the Celtic sea. ICES Journal of Marine Science 54: 896-904.

Tregenza, N.J.C. and A. Collet. 1998. Common dolphin *Delphinus delphis* bycatch in pelagic trawl and other fisheries in the North East Atlantic. Reports of the International Whaling Commission 48: 453-459.

Trippel, E.A. and T.D. Shepherd. 2004. By-catch of harbour porpoise (Phocoena phocoena) in the Lower Bay of Fundy gillnet fishery, 1998-2001. Canadian Technical Report of Fisheries and Aquatic Sciences 2521: iv + 33 pp.

Trippel, E.A., M.B. Strong, C. Hood, C. Richter and J. Lien. 1996. By-catch of harbour porpoise (*Phocoena phocoena*) in the Lower Bay of Fundy gillnet fishery in 1995. Department of Fisheries and Oceans, DFO Atlantic Fisheries Research Document, 96/110: 13 pp.

Trippel, E.A., M.B. Strong, J.M. Terhune and J.D. Conway. 1999. Mitigation of harbour porpoise (*Phocoena phocoena*) by-catch in the gillnet fishery in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 56 (1): 113-123.

Trippel, E.A., J.Y. Wang, M.B. Strong, L.S. Carter and J.D. Conway. 1996. Incidental mortality of harbour porpoise (*Phocoena phocoena*) by the gill-net fishery in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 53: 1294-1300.

Waring, G.T., P. Gerrior, P.M. Payne, B.L. Parry and J.R. Nicolas. 1990. Incidental take of marine mammals in foreign fishery activities off the northeast United States, 1977-88. Fishery Bulletin 88 (2): 347-360.

Waring, G.T., R.M. Pace, J.M. Quintal, C.P. Fairfield, K. Maze-Foley, N. Cabana, P.J. Clapham, T.V.N. Cole, G.L. Fulling, L.P. Garrison, A.A. Hohn, B.G. Maise, W.E. McFee, K.D. Mullin, D.L. Palka, P.E. Rosel, M.C. Rossman, F.W. Wenzel and A.L. Whitingham. 2003. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments - 2003. NOAA Technical Memorandum NMFSNE-182: 287 pp.

Westgate, A.J., A.J. Read, P. Berggren, H.N. Koopman and D.E. Gaskin. 1995. Diving behaviour of harbour porpoises, *Phocoena phocoena*. Canadian Journal of Fisheries and Aquatic Sciences 52: 1064 - 1073.

Woodley, T.H. and A.J. Read. 1991. Potential rates of increase of a harbour porpoise (*Phocoena phocoena*) population subjected to incidental mortality in commercial fisheries. Canadian Journal of Fisheries and Aquatic Sciences 48: 2429-2435.

CHAPTER 3 - METHODOLOGY OF INCIDENTAL CATCH ESTIMATION

3.1 - Introduction

Harbour porpoises are considered to be vulnerable to incidental catches in fishing gears, particularly in bottom-set gillnets (Gaskin 1984; Read and Gaskin 1988; Smith *et al.* 1993; IWC 1994; Larrivée 1996; Trippel *et al.* 1996; Berggren *et al.* 2002; Lesage *et al.* 2004; Stenson 2003). Substantial historical harbour porpoise catches are thought to have occurred in Newfoundland and Labrador waters, since this area has traditionally supported large gillnet fisheries for Atlantic cod (*Gadus morhua*) and other species (Chapters 1, 2). Recent reports from fishers indicate that porpoises continue to be caught despite reduced fishing effort since the cod moratoria ended in the late 1990s (Chapter 2).

Available information on small cetacean bycatch in Newfoundland was summarized by Lien *et al.* (1988), and subsequently by DFO (2001; see Stenson [2003] for a review). Based on logbooks and interviews, Lien *et al.* estimated that the catches of harbour porpoises were likely in the low thousands during the 1980s and early 1990s (Lien *et al.* 1988; Bjørge *et al.* 1994, DFO 2001). These estimates are known to be biased, as they were based upon reported catches by a limited number of fishers, often in restricted areas of the province. Also, total fishing effort in Newfoundland is very difficult to determine, and was not always available for extrapolation of incidental catch rates. Therefore, these previous estimates of incidental catch in Newfoundland must be regarded with caution (DFO 2001).

Incidental catch estimation typically involves the calculation of a catch ratio, which indicates the number or quantity of a particular species over a measure of fishing activity. This can be total weight landed, numbers of nets, soak time of nets, length of nets, fishing trips, net-days, trawl hauls, or even numbers of fishers (e.g. Bjørge *et al.* 1994; Lien 2001; Northridge *et al.* 2003). This ratio is then multiplied by a factor representing a similar measure for the entire fishery in the area of interest, to derive an estimate of incidental catch for a particular fishery in a particular area (and often only during a particular time of year).

The decision on which catch ratio to use depends greatly on the available data: landed catch data is generally available, but concurrent information on the number, soak time and length of nets may not be available, thereby limiting the options. In practice, the vast majority of incidental catch studies have used landed catch, because it is often the only parameter available for analysis. However, there may be significant variability in catches between areas, between fishers in the same area, and even for a single fisher from day to day, particularly for small-boat fishers in nearshore waters. This variability will increase the uncertainty in the incidental catch estimate. In some cases, catch data are available for each fishing trip for each individual fisher, but often, data for longer time periods are combined, further increasing the variability of the dataset.

Another factor to consider is the scale of analysis. Fisheries are often conducted over wide areas, but there may be significant geographical variability in landings between fishers within that area, due to small-scale environmental or biological factors influencing the abundance of the target species. In addition, there may be certain areas that have some special significance to the species (e.g. calving grounds, superior foraging habitat, etc.), where the chance of incidental capture of harbour porpoises is greater than in others. Finally, the distribution of both fisheries and harbour porpoises may vary seasonally, introducing another source of variability that needs to be accounted for.

Because of the potential for significant variability within various fishing effort datasets, the final estimate of incidental catch may vary depending on which metric is used, and at what scale. In this chapter, a series of incidental catch estimates of harbour porpoises will be compared that were calculated using several different methods. This will be used to identify the most suitable method for determining incidental catch of small cetaceans, based on the data that are currently available.

3.2 - Methods

The 2002 nearshore gillnet fishery for Atlantic cod was used to compare measures of incidental catches, for the following reasons. Gillnet fisheries were assumed to pose the greatest risk for incidental entanglement of small cetaceans given their frequent use in Newfoundland fisheries, anecdotal information from fishers concerning incidental catch, previous studies on incidental catches in this area, and known susceptibility of harbour porpoises to incidental catches in gillnets in other areas (Chapter 1). The nearshore cod fishery is of interest due to the large number of participating fishers, as well as the significant amount of effort expended studying this fishery. Finally, 2002 was the last year a commercial gillnet fishery for cod operated along the northeast and west coasts of Newfoundland. This 'Index' fishery had opened in 1998 at quota levels of <10,000 mt in response to industry pressures, but conservation concerns led to closure in 2003.

Datasets were made available from several sources within the Department of Fisheries and Oceans (DFO). Estimates of incidental catch were based on a catch-effort database for vessels ≥35 ft long (10.7 m, hereafter quoted in feet), a fish landings database for vessels <35 ft, a Sentinel Fishery database, and

Marine Mammal Bycatch Collector data. No porpoise incidental catch data were available from the offshore cod fishery off the south coast of the island, and this fishery will therefore not be considered further here.

First, an attempt was made to test whether using soak time (net-days) or target species catch weight (kg, round weight) as estimators of fishing effort made a difference in the incidental catch estimate. The effect of grouping fishing trips into larger sampling units was investigated by subdividing the datasets into 1) a grouping that contained all individual fishing trips for all fishers; or 2) a group that contained combined values of all fishing trips made by individual fishers (i.e., separating different fishers). Both these groupings ("trip per fisher" and "fisher") were used as sampling units to determine if the increased clustering when using the "fisher" grouping might make a difference. Finally, the data were also clustered at three increasing geographic scales, to determine the effect of geography on the analysis. For some fisheries that continued throughout the year, temporal variability was addressed by separating the data into four quarterly subsets, based on month of the year.

3.2.1 - Fishing Effort Data

The two measures used to estimate fishing effort were kg landed catch (round weight) of the target species, and soak time (in net-days). Round weight was calculated from the gutted weight using a set of standard correction factors devised by DFO. These correction factors varied between species. A net-day equated to the number of nets set per day, multiplied by the number of fishing days, where one day equaled 24 hours. Ten nets fishing for one day, and one net fishing for 10 days, both equated to 10 net-days.

3.2.1.1 - Catch-Effort Database for Vessels ≥ 35 Feet Long

The Policy and Economics Branch at DFO in St. John's maintains a catch-effort database for larger vessels (≥35 ft), based on information collected through DFO's Dockside Monitoring Programme (DMP; A.-M. Russell, DFO-NL, pers. comm.). This database contains detailed information on total fish landings per trip, species composition, and landed catch by individual species for all fisheries (both gutted and round weight). However, its usefulness in estimating soak time (in net-days) and amount of gear deployed was limited because these effort estimators were not always recorded reliably by all fishers. When possible, data from the Groundfish Logbook database (see below) were used in combination with the landed catch data to better calculate total fishing duration, or total amount of gear deployed.

3.2.1.2 - Fish Landings Database for Vessels < 35 Feet Long

The landings database maintained by the Policy and Economics Branch at DFO in St. John's contained detailed information on commercial fish landings per trip for small vessels (<35 ft) for all fisheries, based on information collected through DFO's Dockside Monitoring Programme (DMP; A.-M. Russell, DFO-NL, pers. comm.). This database was often the only source of information available for these vessels and contained the total landed weight for all landed species separately. However, this database suffered from both a lack of effort information (no data on either the duration of the trip, or the number of nets deployed by a fisher), and the lack of any detailed geographical information as to where the fish were caught. Due to safety concerns, most fishers do not take small vessels far offshore, and catches were therefore assumed to have been made in waters close to the vessels' home ports (S. Savory, DFO-NL, pers. comm.).

3.2.1.3 - Groundfish Logbook Database

A logbook database for the nearshore fishery for Atlantic cod and associated groundfish was set up in 1997 by the Groundfish Section of the Department of Fisheries and Oceans as an alternative to the Statistics Branch's catch-effort database, which had been considered incomplete and inaccurate in certain areas. This database contained detailed fishing effort data on a per-day basis, including a description of the number of nets used, and the number of hours fished. In the present study it was used to derive a corroborative measure of net-days for all vessels. Unfortunately, this database did not contain all fishing effort as not all fishers submitted their logbooks, despite the fact that cooperation with this programme is a DFO licensing requirement.

3.2.2 - Incidental Catch Data

3.2.2.1 - Marine Mammal Bycatch Collector Database

The Marine Mammal Bycatch Collector dataset consisted of extremely detailed reports on a variety of fisheries, collected by a small group of dedicated commercial fishers (n = 45 fishers in 2002). Fishers in this programme were most active in the nearshore gillnet fisheries for Atlantic cod, lumpfish, and winter flounder, although some also fished for Atlantic herring. These fishers were originally selected because they participated in fisheries that were known to have high incidental catches of seals (e.g. lumpfish fishery). However, small cetaceans, especially harbour porpoise, were also reported regularly. From 2001 onwards, the programme was set up to provide increased information on cetaceans, in addition to seals. Participating fishers recorded location of sets, water depth, net characteristics, the number of nets hauled daily, length in the water, and catch (fish, seabirds and marine mammals) and discards. In many cases, the information on location of catches was limited (usually identified by a local landmark) and the boats employed were small, so it is assumed that the majority of catches were made close to the home port. Over 80% of fishers who initially agreed to collect the requested information sent in their forms within the same year, although this rate declined slightly in following years, and reminder letters had to be sent in several cases (W. Penney, DFO-NL, pers. comm.). As part of this programme, fishers received special dispensation from DFO to land harbour porpoise (W. Penney, DFO-NL, pers. comm.).

3.2.2.2 - Sentinel Fishery Database

The Sentinel Fishery database consists of detailed fisheries data collected through the scientifically managed Sentinel Fishery for cod (n = 81 in 2002). The Sentinel fishery was established in 1995 after the introduction of the groundfish moratoria to enable a continued monitoring of the cod stocks in nearshore waters by fishing under scientifically designed protocols (FRCC 1994). Almost all vessels involved were <35 ft, and their effort was limited, typically involving up to 6 nets for periods less than 24 hours, at predetermined geographical locations. Despite this, the fishery was considered to be generally comparable to the commercial nearshore cod fishery, which fishes with similar gears within the same geographic area (D. Maddox-Parsons, DFO-NL, pers.comm.). As such, the Sentinel Fishery data offered an opportunity to obtain comparative measures of fishing effort for the small-boat, nearshore fisheries for Atlantic cod. Fishers participating in the Sentinel Fishery reported incidental catches of marine mammals to DFO's Marine Mammal Section in St. John's, which were combined with their reported fishing effort. Sentinel fishery catch per unit effort (net-day) data were compared with Bycatch Collector data from the same time and area to determine if datasets could be combined, using resampling methodology (Resampling Stats in MS Excel; Blank *et al.* 2001). Where data did not differ significantly, Sentinel catch reports were incorporated into the total catch estimates for that particular area and period of the year.

3.2.3 - Deriving Small Cetacean Incidental Catch Estimates

Small cetacean incidental catch events were recorded in the Bycatch Collector and Sentinel datasets. Rates of incidentally caught small cetaceans obtained from these datasets were extrapolated to the entire fishery, based on data from the fish landings database, the catch/effort database, and groundfish logbook data. Units of effort used in these calculations were total weight of landed catch of target fish species (in kg round weight) and number of net-days. Effort of each fisher was identified based on unique vessel codes included in the fish landings and catch/effort datasets, which had been made available through DFO's Licensing Section. For most vessels <35 ft, only landed catch was available as a measure of effort, and it was necessary to estimate the number of net-days of effort for these vessels. These estimates were based on the relationship between landed catch and net-day that were derived from the Bycatch Collector, Sentinel and groundfish logbook datasets. For each fishing trip or fisher (depending on which sampling unit was used), the ratio of kg landed catch per single net-day was calculated. These ratios were averaged over the area and period in question, and the resulting average (kg landed catch/net-day) ratio was then applied to the total amount of landed catch to estimate the equivalent numbers of net-days.

Nearshore cod gillnet fisheries catch/effort and incidental catch data were analysed based on time of year (divided into January-March, April-June, July-September, and October-December), and area (divided by NAFO areas). Data were analysed at three increasing geographical scales: at the scale of individual NAFO areas; at the "coastline" scale, lumping adjacent NAFO areas together into three 'coastlines' to the northeast, the south and west of the island; and at the "island" scale, combining all data for the entire island. The "coastline" scale consisted of the south coast (NAFO areas 3Pn, 3Psa, 3Psb, 3Psc and 3Lq combined), the northeast coast (NAFO areas 3Ka, 3Kd, 3Kh, 3Ki, 3La, 3Lb, 3Lf and 3Lj combined), and west coast (NAFO areas 4Ra–d combined; see Figs. 1.2, 1.3, 1.4). Compared to other parts of the province, the intensity of gillnet fishing effort off the coast of Labrador was very limited. Also, for logistical reasons this area could not be visited by DFO technicians. The small amount of gillnet fishing effort off coastal Labrador (most in NAFO unit 2Jm) was therefore excluded from further analysis.

Incidental catch rates were calculated using either individual fishers (identified by their vessel codes) or fishing trips of individual fishers as sampling units. Marine Mammal Bycatch Collector and Sentinel datasets were combined when catch rates per unit effort did not differ significantly; in other cases, only Bycatch collector data were used, where available. Sentinel data were only used in isolation if no other effort data were available. Catch rates per trip were averaged to obtain the estimated incidental catch rate for a particular area and period. An example is given in Appendix 1. The main sources of variability in both Bycatch Collector and Sentinel datasets were variation in cod catches between different fishers, differing by as much as several orders of magnitude, and variation in cod catches on different trips for individual fishers, which only became apparent when analyzing individual trips per fisher.

Sample size under consideration was frequently small, and the residuals in the various samples were not distributed normally around the mean of each sample. This precluded the use of parametric tests to analyse the incidental catch data (Efron and Tibshirani 1993; Simon 1997). The uncertainty associated with estimates of incidental catch was derived using a resampling procedure (Resampling Stats in MS Excel; Blank *et al.* 2001). Unlike conventional statistics, resampling methodology does not require assumptions about the distribution of residuals in the dataset, and can be used with comparatively small samples.

These incidental catch rate values were resampled 10,000 times, with replacement, while using incidental catch estimates per fisher or trip per fisher for the relevant geographical scale as resampling units. The overall mean, and the upper and lower 95% confidence limits, were then used as incidental catch rates. Irrespective of the geographical scale of analysis, catch estimates were summed across areas to deliver final catch estimates for the entire island, per period. To present data summaries, the variances of the point estimates were summed to provide a range (95^{th} percentile) to approximate confidence intervals (e.g. it is assumed that the variance of the sum of the point estimates is equal to the sum of the separate point estimate variances; M. Koen-Alonso, DFO-NL, pers. comm.). At the smallest scale of individual NAFO units, only those areas for which detailed reports from Bycatch collectors or Sentinel fishers were available were used for the incidental catch estimation analysis, thus potentially underestimating levels of incidental catch. At larger scales, the average incidental catch rate from sampled areas was applied to adjacent, unsampled areas.

3.3 - Results

3.3.1 - The Nearshore Fishery for Atlantic Cod

In 2002, approximately 2,700 vessels landed catch as part of the Atlantic cod fishery. The total landed catch was approximately 12,000 mt (round weight), of which 10,200 mt (~ 90%) was cod. Most of this was caught along the south coast of Newfoundland, where the returns from the fishery have remained relatively stable in recent years (DFO 2004a; Figs. 3.1 A-D). Approximately 67%

of landed catches occurred in the third quarter of the year, but some fishing activity continued throughout the year, particularly along the south coast. Both Bycatch Collectors and Sentinel fishers were active throughout the commercial fishing season on all coasts, while Sentinel fisheries also occurred outside this period. Both Sentinel fishers and Bycatch Collectors were distributed throughout the island. During 2002, a total of 45 Bycatch Collectors recorded data during 453 fishing trips. At the same time, 81 Sentinel fishers recorded data for 1,672 trips. In most cases, nets were left fishing for approximately 24 hours, but occasionally storms or technical difficulties prevented fishers from retrieving their nets, and soak times increased accordingly.

3.3.2 - Records of Incidental Capture of Small Cetaceans

A total of 64 small cetacean entanglements were reported in 2002 by Bycatch Collectors, Sentinel fishers, and other fishers who were not involved with either program. Of these, 44 specimens were collected and identified by DFO technicians. All collected specimens were harbour porpoises, but the incidental capture of other species of small cetaceans cannot be discounted.

Of the 64 reported entanglements, 10 were reported by fishers who were not involved with either the Sentinel or the Bycatch Collector programme, but who had become aware of DFO's research efforts through word of mouth. However, there were no fishing effort data associated with them and they were excluded from further analysis. The remaining 54 catch events were distributed evenly among Bycatch Collectors (26 caught; 12 collected and identified as harbour porpoise) and Sentinel fishers (28 caught; 22 collected and identified as harbour porpoise). Of the 26 capture events in the Bycatch Collector dataset, 19 were reported from the nearshore cod fishery (9 collected and identified as harbour porpoise). The remaining 7 capture events took place in the nearshore fishery for Greenland halibut and the offshore fishery for monkfish and skate. These events will be discussed in greater detail in Chapter 4. In all, a total of 47 capture events were reported in the nearshore cod fishery in 2002, of which 31 were collected and identified as harbour porpoise.

3.3.3 - Small Cetacean Incidental Catch Estimates for Nearshore Newfoundland Cod Gillnet Fisheries in 2002

Tables 3.1 and 3.2 list the incidental catch estimates for small cetaceans at increased geographic scales, with all estimates for the entire island combined, by quarter, using either kg landed catch (round weight) or net-days, based on either fishers or trips per fisher. The majority of estimated catches occurred during the third quarter. In several instances, resampling proved impossible due to insufficient sample sizes.

Unsurprisingly, most incidental catches were estimated to occur along the south coast, where most fishing effort occurred. In all cases, incidental catch estimates based on kg landed fish catch were larger than estimates based on net-days. When using trips per fisher, catch estimates based on landed catch were consistently greater than estimates based on net-days. This difference was not as pronounced when using data based on fishers. Incidental catch rates were generally low, with slightly higher rates along the south coast. Rates among the NAFO units varied greatly, even within the same time period.

3.4 - Discussion

Incidental catch of harbour porpoise and other small cetaceans occurs regularly in the gillnet fisheries that are active in Newfoundland and Labrador. Although the nearshore fishery for Atlantic cod has been reduced in effort since the early 1990s, many fishers still target this species, thereby potentially causing high levels of small cetacean incidental catch.

3.4.1 - Fishers versus Trips per Fisher

It was suggested by reviewers of an earlier draft of this document that resampling also be conducted using "fishing trip per fisher" as a sampling unit. When net-days were used as a measure of effort, choosing individual fishers as sampling units typically resulted in larger variability in the incidental catch estimates than when using “trips per fisher”, as evidenced by the 95% confidence intervals in Tables 3.1 and 3.2, making "trips per fisher" the preferred sampling unit where net-day data were available (Lawson *et al.* 2004; Tables 3.1, 3.2).

In several cases, sample size was small when using individual fishers as sampling units, particularly at the smallest geographical scale of NAFO areas. When n was less than 20, no resampling was attempted, because it was felt that the variability between different resampling runs would be so large as to invalidate overall resampling assumptions of similarity between runs (Lunneborg 2000; Beleites *et al.* 2005). This meant that, in these cases, no 95% confidence interval could be calculated. This problem did not occur when using "trips per fisher" as sampling units, due to the far greater sample sizes available for resampling.

In conclusion, the usage of "trips per fisher" is considered to be preferable to "fisher", particularly when using net-days as measure of fishing effort, due to the generally smaller confidence intervals, and the greater sample size.

3.4.2 - Landed Catch versus Net-day

There were differences between incidental catch rates for net-days and kg landed catch, but these were not consistent in direction. Incidental catch rates estimated using landed catch were higher and more variable than those obtained using net-days (Tables 3.1, 3.2). The primary cause appears to be the magnitude of the underlying day-to-day variability in catches of fish, even for individual fishers at the same geographical location. The maximum number of nets used is typically limited through fishing license conditions, and the soak time is likely to be kept to a minimum due to the significant reduction in quality (and thus monetary value) of cod after being entangled for longer than 1-2 days (P. Walsh, MI-MUN, pers. comm.). The resulting lower variability is the main reason why net-days are preferred over landed catch as a measure of fishing effort.

In addition, several hauls did not contain any fish catch at all, but incidental catch did occasionally occur in these hauls. In these cases, an average value of landed catch for that individual fisher had to be used to calculate an incidental catch / landed catch ratio, increasing the uncertainty of the final catch estimate. This problem did not occur when using net-days, since the soak time was not directly influenced by the lack of catch. Net-days measure actual fishing effort, rather than a proxy of effort (kg landed catch), and are therefore preferable.

Annual incidental catch estimates based on landed catch were on the order of several thousand to more than 10,000 porpoises caught per year, depending on geographic scale and the usage of "fishers" or "trips per fisher" as sampling units. Although confidence intervals are extremely large, these estimates appear unrealistically high relative to the number of reports of incidental catch of small cetaceans in the nearshore fishery. No population estimates currently exist for harbour porpoise in Newfoundland waters, but catch rates in the high thousands would likely have translated in estimates of many hundreds of thousands of porpoises, which would probably lead to the species being reported more frequently than is currently the case. Sightings of harbour porpoises in nearshore waters appear to have increased after the moratoria were announced, suggesting the possibility of release from fisheries pressure, although this has not been thoroughly studied and may also reflect greater focus on cetaceans among the public (J. Lien, MUN, pers. comm.). Nonetheless, annual incidental catch estimates of high hundreds to low thousands appear to be most likely given anecdotal reports of porpoise abundance and lack of complaints from fishers.

In conclusion, net-days are generally less variable than landed catch as a measure for fishing effort. For this reason, as well as the fact that soak times, unlike landed catch, cannot be zero, and measure actual fishing effort, the use of net-days as a measure for fishing effort is recommended where such data are available.

3.4.3 - The Effect of Increasing Geographic Scale

Incidental catch estimates were lowest at the smallest geographic scale of NAFO areas. This was likely caused by absence of coverage in some areas, and limited coverage in others, leading to an underestimation of incidental catch at this geographic scale. This indicates the importance of achieving sufficient coverage for data collection. Under the present data collection regime, the distribution of collaborating Sentinel fishers was governed to a large extent by financial considerations in the Department of Fisheries and Oceans. In later years, the number of fishers participating in the Sentinel programme was reduced as a measure to reduce costs.

Incidental catch estimates were greatest at the "coastline" scale, but in the majority of cases, estimates at the coastline and island scale were of the same order of magnitude. Analysis at the coastline scale would appear to be most useful to take account of the regional variability in fisheries management regulations. The coastline scale also makes more sense on a biological basis given that it is unlikely that porpoise either restrict themselves to a single NAFO unit or are distributed uniformly across the island.

With only small numbers of reported incidental catch events, there are areas where no incidental catch was reported in a given quarter, and where therefore the estimated incidental catch rates were zero. At the smallest geographic scale (NAFO unit level), there were 68 potential values (four quarters of the year, for 17 different NAFO units). Of these 68 values, 16 did not have any fishing effort associated with them (i.e. no fishing activity occurred, mostly during the first quarter); while six did have an active fishery, but no detailed catch/effort reports were available (i.e. none of the Bycatch Collectors or Sentinel fishers was fishing in the area during that time). 32 of these 68 values were zeroes based on at least one reporting fisher, and 14 of the 68 values were greater than zero. The "coastline" level of analysis appeared to represent the best balance between adequate sample size for resampling and the proportion of cells that contained no data or zero incidental catch.

In conclusion, performing the analysis for incidental catch of small harbour porpoises at the "coastline" scale appears to be a reasonable compromise between the need for geographic detail and the realities of imperfect data collection protocols. As well, there is reason to believe that this scale most accurately reflects harbour porpoise distribution. For this reason, this scale is considered to be preferable for studying small cetaceans. However, other species with different distributions may require analysis at a different scale.

3.4.4 - Caveats for Incidental Catch Estimation

A number of factors have the potential to decrease the accuracy of the incidental catch estimates from this, and similar, studies:

1. Generally, sample sizes are small: in several NAFO areas fewer than five fishers collected data, although most undertook numerous trips;

2. Bycatch Collectors do not always include all their fishing effort in their reporting sheets, and some do not send in all their sheets, leading to an underestimation of fishing effort and potentially of incidental catches;
3. Detailed geographical data (latitude, longitude) for catches from small vessels are often unavailable, and this will be particularly problematic for fishers operating near the margins of several NAFO areas, as they may be arbitrarily assigned to one or the other area;
4. It is unclear whether the subsample of fishers used to derive incidental catch multipliers in this study could be unrepresentative of the entire fleet. Sentinel fishing data collection does not automatically occur in the same place and time as commercial fisheries, making them potentially unrepresentative as incidental catch estimators for the commercial fleet (Lesage *et al.* 2004).
5. Inaccurate reporting may occur due to difficulties in correct cetacean species identification by some fishers, or underreporting (see pt.2). Deploying dedicated observers on every boat has been suggested as a means to improve incidental catch reporting. However this is impractical for many Newfoundland fisheries as most vessels are small and the cost of such a programme would be prohibitive. In this study, participating Bycatch Collectors and Sentinel fishers are unlikely to underreport their incidental catches given their skill and motivation (i.e., most have a long

working relationship with DFO's Marine Mammals Section, and are not at risk of sanctions if they report catches of small cetaceans).

3.5 - Conclusions

The data analyzed in this study show that incidental catch of harbour porpoise is still occurring in the nearshore Atlantic cod fishery, despite the reduction in the scope of this fishery over the last decade. Several different methods were used to estimate incidental catch, using either "fisher" or "trips per fisher" as sampling units; using either "net-days" or "kg landed catch" as a measure of fishing effort; and assessing the effect of performing these analyses at increasing geographical scales. Based upon this research, the following suggestions are made:

- The usage of "trips per fisher" is considered to be preferable to "fisher", particularly when using net-days as a measure of fishing effort, due to the generally smaller confidence intervals, and the greater sample size available for resampling.

- Net-days are generally less variable than landed catch as a measure for fishing effort. For this reason, as well as the fact that soak times, unlike landed catch, cannot be zero, the use of net-days as a measure for fishing effort is recommended where data are available.

- Performing the analysis for incidental catch of small harbour porpoises at the "coastline" scale appears to be a reasonable compromise between the need for geographic detail and the realities of imperfect data collection protocols. As well, there is reason to believe that this scale most accurately reflects both harbour porpoise distribution and the scale of fisheries management. For this reason, this scale is considered to be preferable for studying small cetaceans in this province.

Based on the significant variability encountered in the dataset, the preferred mode of analysis for the estimation of incidental catch of small cetaceans would be to use "trips per fisher" as sampling units, net-days as an estimator of fishing effort, and to cluster data at the "coastline" geographic scale.

3.6 - References

Beleites, C., R. Baumgartner, C. Bowman, R. Somorjai, G. Steiner, R. Salzer and M.G. Sowa. 2005. Variance reduction in estimating classification error using sparse datasets. Chemometrics and Intelligent Laboratory Systems 79: 91-100.

Berggren, P., J. Carlström and N. Tregenza. 2002. Mitigation of small cetacean bycatch; evaluation of acoustic alarms (MISNET). European Commission Directorate-General, Brussels: 29 pp.

Bjørge, A., R.L.J. Brownell, G.P. Donovan and W.F. Perrin. 1994. Significant direct and incidental catches of small cetaceans. A report by the Scientific Committee of the International Whaling Commission to the United Nations Conference on Environment and Development (UNCED). Report of the International Whaling Commission 15 (Special issue): 75-130.

Blank, S., C. Seiter and P. Bruce. 2001. Resampling stats in Excel. Version 2. Resampling Stats, Inc., Arlington, VA, USA.

COSEWIC. 2003. COSEWIC assessment and update status report on the harbour porpoise *Phocoena phocoena* (Northwest Atlantic population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON: vii + 30 pp. Available online at: http://www.sararegistry.-gc.ca/virtual_sara/files/cosewic/sr_harbour_porpoise_e.pdf.

DFO[Department of Fisheries and Oceans]. 2001. Proceedings of the International Harbour Porpoise Workshop, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canadian Science Advisory Secretariat, Proceedings Series 2001/042: 47 pp.

Efron, B. and R.J. Tibshirani. 1993. An introduction to the Bootstrap. Chapman and Hall, New York, NY, USA.

Gaskin, D.E. 1984. The harbour porpoise *Phocoena phocoena* (L.): regional populations, status, and information on direct and indirect catches. Reports of the International Whaling Commission 34: 569-586.

IWC [International Whaling Commission]. 1994. Report of the Workshop on Mortality of Cetaceans in Passive Fishing Nets and Traps. Reports of the International Whaling Commission 15 (Special Issue): 6-57.

Larrivée, M.-L. 1996. Étude des prises accidentelles de marsouins communs, *Phocoena phocoena*, dans les filets maillants pour la région de gulfe et de l'estuaire de Saint-Laurent (Canada). M.Sc. thesis, Laval University, Québec City, PQ, Canada.

Lawson, J., S.Benjamins and G. Stenson. 2004. Harbour porpoise bycatch estimates for Newfoundland's 2002 cod fishery. Canadian Science Advisory Secretariat Research Document 2004/066: 32 pp.

Lesage, V., J. Keays, S. Turgeon and S. Hurtubise. 2004. Incidental catches of harbour porpoises (*Phocoena phocoena*) in the gillnet fishery of the

Estuary and Gulf of St. Lawrence in 2000-2002. Canadian Technical Report of Fisheries and Aquatic Sciences 2552: 37 pp.
Lien, J. 2001. Incidental bycatch of harbour porpoise in Newfoundland and Labrador-as we know it. Paper presented at the Department of Fisheries and Oceans' International Harbour Porpoise Workshop, Dartmouth, NS, Canada, 26-28 March 2001: 12 pp.
Lien, J., W. Ledwell and J. Nauen. 1988. Incidental entrapments in fishing gear during 1988: a preliminary report to the Newfoundland and Labrador Department of Fisheries and Oceans, Newfoundland Region. Memorial University of Newfoundland, St. John's, NL: 27 pp.
Lunneborg, C.E. 2000. Data analysis by resampling: Concepts and applications. Duxbury Press, Pacific Grove, CA, USA.
Northridge, S., D. Sanderson, A. Mackay and P.S. Hammond. 2003. Analysis and mitigation of cetacean bycatch in UK fisheries. Final Report to DEFRA project MF0726. University of St. Andrews, St. Andrews, Fife, Scotland, U.K.: 25 pp.
Read, A.J. and D.E. Gaskin. 1988. Incidental catch of Harbour Porpoises in Bay of Fundy groundfish gill nets. Jounal of Wildlife Management 52(3): 517-523.
Simon, J.L. 1997. Resampling: The New Statistics. Resampling Stats, Inc., Arlington, VA, U.S.A.
Smith, T., D. Palka and K. Bisack. 1993. Biological significance of bycatch of harbor porpoise in the Gulf of Maine demersal gillnet fishery. Northeast Fisheries Science Center, Woods Hole, MA: 15. Available online at:
Stenson, G.B. 2003. Harbour porpoise in the North Atlantic: Abundance, removals, and sustainability of removals. NAMMCO Scientific Publications 5: 271-302.
Trippel, E.A., J.Y. Wang, M.B. Strong, L.S. Carter and J.D. Conway. 1996. Incidental mortality of harbour porpoise (*Phocoena phocoena*) by the gill-net fishery in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 53: 1294-1300.

CHAPTER 4 - RECENT SMALL CETACEAN INCIDENTAL CATCH IN GILLNET FISHERIES OF NEWFOUNDLAND AND LABRADOR, CANADA

4.1 - Introduction

Despite reduced fishing effort in many North Atlantic fisheries following the closure of the commercial groundfish fishery in the early 1990s, concerns remain about the viability of a number of harbour porpoise (*Phocoena phocoena*) populations (Stenson 2003). Although potential limiting factors for these populations include habitat change, changes in prey abundance or distribution, marine pollutants, and global warming (Donovan and Bjørge 1995, Aguilar and Borrell 1995, Brodie 1995, Hutchinson 1996, Teilmann and Lowry 1996, Anonymous 1999, Koschinski 2002), a primary concern continues to be the levels of direct mortality, primarily through incidental catches in fishing gear. The harbour porpoise is recognized as a species particularly vulnerable to incidental catches in fishing gear; bottom-set gillnets, and to a lesser extent fish weirs and traps, represent gear types most often responsible for takes of harbour porpoises (Christensen and Lear 1977; Gaskin 1984; Read and Gaskin 1988; Smith *et al.* 1993; IWC 1994; Jefferson and Curry 1994; Read 1994b; Barlow and Hanan 1995; Larrivée 1996; Trippel *et al.* 1996; Tregenza *et al.* 1997b; Caswell *et al.*

1998; Northridge and Hofman 1999; Trippel *et al.* 1999; Vinther 1999; IWC 2000; Berggren *et al.* 2002; Koschinski 2002; Stenson 2003; Lesage *et al.* 2004).

Numerous reviews have concluded that large numbers of porpoises are caught in commercial fishing gear throughout their range, but that catches appeared highest in the north Atlantic (e.g. Jefferson and Curry 1994, Read 1994, Donovan and Bjørge 1995, Anonymous 1998, CEC 2002, Stenson 2003). This situation prompted the IWC to formally recognize the western north Atlantic stocks of the harbour porpoise as one of several small cetacean stocks worldwide that were under severe pressure from incidental capture in passive fishing gear, including gillnets (IWC 1994). The IWC recognised that no single solution to alleviate fisheries-related cetacean incidental catch existed that could be applied to all fisheries around the world (IWC 1994).

Based upon declining sightings and/or the perceived impacts of incidental catches, many porpoise populations have been classified as being in danger by either national or international groups responsible for assessing the status of animals. In Atlantic Canada, harbour porpoises are currently listed as 'Special Concern' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2003c), while the International Union for the Conservation of Nature (IUCN) considers harbour porpoises to be 'Vulnerable' throughout their range (Klinowska 1991).

Although harbour porpoise incidental catch occurs in a number of fisheries in Newfoundland waters, there are few defendable estimates (Lien *et al.* 1988; DFO 2001). Substantial harbour porpoise catches are thought to have occurred in the past since this area has traditionally supported large gillnet fisheries, particularly for Atlantic cod. Previous information on cetacean incidental catch in Newfoundland was summarized by Lien *et al.* (1988), and subsequently DFO (2001); see Stenson (2003) for a review. Based on logbooks and interviews, Lien estimated that the incidental catch of harbour porpoises was likely in the low thousands during the 1980s and early 1990s (Bjørge *et al.* 1994, DFO 2001). However, these estimates were based upon reported catches by a limited number of fishers, often in restricted areas of the province. Also, total fishing effort in Newfoundland is very difficult to determine. Therefore, these previous estimates of incidental catch in Newfoundland must be regarded with caution (DFO 2001).

As in most areas of the northwest Atlantic, effort in the Newfoundland cod fishery has been reduced significantly since the early 1990s. This fishery, which accounted for the majority of harbour porpoises caught in this area (Lien *et al.* 1994, Read 1994, DFO 2001), was closed off the northeast coast of Newfoundland in 1992, and along the south coast in 1993. Cod gillnet fisheries have reopened since 1997, but at reduced levels. The fishery off the northeast and west coasts of Newfoundland was closed again in 2003, but reopened in 2006. Incidental catches of porpoise were probably significantly reduced during these moratoria (DFO 2001) and may continue to be less than prior to the moratoria, although recent reports indicate that porpoises continued to be caught despite reduced fishing effort since reopening of these fisheries in the late 1990s. Evidence of similar reductions in incidental catch due to reductions in fishing effort is available for the Bay of Fundy/Gulf of Maine population (Rossman and Merrick 1999, Waring *et al.* 2001; Trippel and Shepherd 2004).

In general, there has been little effort to monitor marine mammal incidental catch in fisheries in Newfoundland and Labrador. Data are available through a fisher's logbook programme, combined with directed phone surveys and interviews. Vessel-based independent observers have been recommended as the best means to monitor incidental catch, but this system has not been implemented widely in Newfoundland and Labrador, partly because much of the local fishery is conducted using small vessels (<10 m; IWC 1994). Dedicated fisheries observers are present aboard some larger fishing vessels (e.g. DFO's Fishery Observer Programme), but they provide limited coverage of the fleet, and their primary duty is to document catch level of directed species rather than identifying marine mammal incidental catch. Since 1989, DFO-NL's Marine Mammal Section has maintained a network of dedicated fishers spread throughout the province, who collect and report marine mammal incidental catch, as well as detailed fishing effort data. In addition, fishers involved with the scientifically-managed Sentinel fishery for Atlantic cod were contacted, and asked to retain and report small cetacean catches.

In 2001, additional effort was placed on optimizing data collection on small cetacean catches by fishers participating in the logbook programme. Subsequently, a review of all available data on fishing effort and catches of harbour porpoise was initiated to improve the understanding of harbour porpoise incidental catch in Newfoundland and Labrador.

The goal of this chapter is to estimate incidental catch of small cetaceans in nearshore and offshore gillnet fisheries in Newfoundland and Labrador, for the years 2001, 2002 and 2003. The fisheries for which incidental catch of small cetaceans was estimated include the gillnet fisheries for Atlantic cod, lumpfish (*Cyclopterus lumpus*), Atlantic herring (*Clupea harengus*), monkfish (*Lophius americanus*), skates (Rajidae), white hake (*Urophycis tenuis*), Greenland halibut (*Reinhardtius hippoglossoides*), redfish (*Sebastes* sp.), and winter flounder (*Pseudopleuronectes americanus*). These fisheries were chosen based on previous anecdotal reports of incidental catch from various sources in the fishery, as well as their potential to generate incidental catch of small cetaceans due to location or fishing season. Incidental catch estimates were calculated according to the methodology described in Chapter 3. Based on these estimates, the relative importance of the different fisheries will be assessed in terms of the risk of incidental catch to small cetaceans.

4.2 - Methods

Estimates of harbour porpoise incidental catch were made using incidental catch rate multipliers derived from captured porpoises reported by Bycatch Collectors, Sentinel fishers and Fishery Observers. The focus of this study was on gillnet fisheries, since these were assumed to pose the greatest risk for incidental entanglement of small cetaceans in the current Newfoundland fisheries environment. Data were grouped geographically based on Northwest Atlantic Fisheries Organization (NAFO) divisions of waters around Newfoundland (Figs. 1.3, 1.4).

Databases used to estimate incidental catch in this study included a catch-effort database for vessels ≥35 ft long (10.7 m, hereafter quoted in feet), a fish landings database for vessels <35 ft, a Fishery Observer database, a Sentinel Fishery database (see Chapter 3), and Marine Mammal Bycatch Collector data (see below). Together, these databases covered the vast majority of catches in all types of gillnet fisheries currently active in the province.

4.2.1 - Fishing Effort Data

Fishing effort datasets used to estimate incidental catch of small cetaceans were described previously in Chapter 3. However, some additional information was required to estimate total catches and net-days for offshore fisheries conducted by the larger vessels (≥ 35 ft). Some vessels fishing off the province's south coast occasionally landed their catch in Nova Scotia, which meant that information for those trips was not incorporated in the original catch-effort database. These records were subsequently added from a separate dataset that incorporated all catch data by Canadian vessels irrespective of its origin (D. Kulka, DFO-NL, pers. comm.).

4.2.2 - Incidental Catch Data

Datasets used to estimate incidental catch of small cetaceans have been described in Chapter 3. However, the coverage of offshore fisheries by Bycatch Collectors was very limited, and the Sentinel dataset was restricted to nearshore waters. The only available data on incidental catch of small cetaceans in offshore fisheries were collected through DFO's Fishery Observer Programme, which is described below (D. Kulka, DFO-NL, pers. comm.). No Bycatch Collector was active in the fishery for white hake during 2001-2003. Sentinel fishers were not asked to report incidental capture in any other fishery than their Sentinel gillnet fishery for cod, unless they were specifically recruited for that purpose to the Bycatch Collector Programme by DFO technicians, in which case their Sentinel fishing data were treated separately from other commercial fishing records. For logistical reasons, DFO technicians were unable to include fishers targeting cod and lumpfish along the southeastern coast of Labrador (NAFO unit 2Jm) in the Bycatch Collector programme, and this region was therefore not included in the present analysis.

4.2.2.1 - Fishery Observer Database

The Newfoundland and Labrador Fishery Observer Programme was formerly run directly by the Department of Fisheries and Oceans, but is currently contracted to SeaWatch Inc., a company based in St. John's, NL. The observers' main task was monitoring incidental catches of various fish species, particularly those currently under moratorium, such as Atlantic cod, American plaice (*Hippoglossoides platessoides* Fabricius), and redfish (Kulka *et al.* 2000). In addition to providing information on marine mammal incidental catch it also provided an independent estimate of fishing effort. Data from trips that included a fisheries observer were compared to the records for the same trips in other databases and used to correct for reporting errors. Observers recorded the exact amounts of catch and discards, geographical location, depth, duration of haul, number and length of nets. This database is biased towards certain fisheries and vessel sizes, as over 80% of observing effort for gillnetting fisheries currently takes place on vessels targeting deepwater species such as Greenland halibut and monkfish. Observers were placed on fishing vessels based primarily on the volume and economic value of the target species catch, rather than according to a scientific allocation scheme. Coverage was estimated based on the percent of total landed catch that was observed in each directed fishery; time spent fishing was not accounted for (J. Firth, DFO-NL, pers. comm.). Since the fishing sector contributes 70% of the costs required to run the observer programme (typically by means of a levy on sold catches; J. Firth, DFO-NL, pers. comm.), the bulk of observer activity takes places on vessels fishing for economically important species such as snow crab (*Chionoecetes opilio* Fabricius) and northern shrimp (*Pandalus* sp.). In these fisheries, close to 100% coverage of fishing effort may be achieved (J. Firth, DFO-NL, pers. comm.). In practical terms, there is only limited opportunity for Fishery Observers to board the smallest vessels <35 ft long, and there is no protocol in place to ensure randomized deployment of observers on these vessels (J. Firth, DFO-NL, pers. comm.). There is presently no legal requirement to monitor fisheries in Canadian waters for incidental catch of small cetaceans or other species, so the results from this observer programme are potentially negatively biased (B. Wong, DFO, pers. comm.). For this reason, the Fishery Observer database was only used when no other datasets were available, such as in the offshore fisheries for cod, monkfish and skates, white hake, redfish and Greenland halibut.

4.2.3 - Deriving Estimates of Small Cetacean Incidental Catch

Small cetacean incidental catch events were recorded through the data collection programmes described above. Rates of incidentally captured small cetaceans per unit effort obtained from the Sentinel and Bycatch Collector logbooks were extrapolated to the entire fishery based on data from the fish landings database and groundfish logbook data (Table 4.3). The unit of effort used in these calculations was the number of net-days (Chapter 3).

Nearshore gillnet fisheries catch/effort and incidental catch data were organised based on time of year (divided into four quarters where relevant: January-March, April-June, July-September, October-December), and area (based on NAFO units). Nearshore fisheries around the island of Newfoundland were defined as those fisheries occurring in NAFO units immediately adjacent to land, while offshore fisheries occurred outside these waters. Nearshore fisheries were geographically aggregated to correspond to the three coastlines surrounding the island of Newfoundland (northeast coast: NAFO units 3KadhiLabfj; south coast: 3LqPnPsabc; and west coast 4Rabcd; Figure 1.4), and analysed for all three coasts separately. Incidental catch estimation analyses were performed at the geographic scale of coastlines, because it appeared unlikely that porpoise either restricted themselves to a single NAFO unit or are distributed uniformly around the island of Newfoundland (Johnston *et al.* 2005). Also, management regimes for nearshore fisheries in the area are typically set up at this scale (Chapter 3). For logistical reasons, no data on bycatch of small cetaceans could be collected in the nearshore fisheries for cod and lumpfish that were conducted along the southeastern coast of Labrador (NAFO unit 2Jm), and this region has been excluded from further analysis.

For offshore fisheries, the following geographic stratification scheme was used (based on a combination of oceanographic and NAFO jurisdictional boundaries; see Figs. 1.2, 1.3, 1.4):

- 0A/B (arctic waters in Baffin Bay and Davis Strait)
- 2GHJ3K (subarctic waters off Labrador and northeastern Newfoundland, characterized by a relatively narrow continental shelf)
- Northeast coast (identical to nearshore fisheries)
- 3LN (the eastern and northeastern part of the Grand Banks, influenced by the Labrador Current)
- 3M (the Flemish Cap)
- 3OPs (the southern and southwestern part of the Grand Banks, influenced by the north Atlantic Current)
- South coast (identical to nearshore fisheries)
- West coast (identical to nearshore fisheries)

This stratification scheme was only employed when dealing with Fishery Observer data of offshore fisheries. This stratification scheme may not take into account variability at a smaller scale. However, it was felt that these larger areas provide a reasonable preliminary assessment of these fisheries, where incidental catches of small cetaceans have not been studied in detail (D. Kulka, DFO-NL, pers. comm.).

In many cases, only landed catch was available as a measure of effort, and it was necessary to estimate the number of net-days of effort per trip for these fishers. These estimates were based on the relationship between landed catch and net-day that were derived from the groundfish logbook database. For each fishing trip, the ratio of kg landed catch per single net-day was calculated. These ratios were averaged over the area and period in question, and the resulting average (kg landed catch/net-day) ratio was then applied to the total amount of landed catch to estimate the equivalent numbers of net-days. Data from trips monitored by a Fishery Observer were compared to the records for the same trips in other databases and used to correct for reporting errors, if any.

Small cetacean incidental catch rates were calculated using fishing trips of individual fishers as sampling units (Chapter 3). The nearshore landings database was organized based on trips, determined by sailing and landing dates. For offshore fisheries, where trips could take several days, the database organization was based on individual hauls that had to be aggregated into trips in order to be used as comparable sampling units. When deriving a small cetacean incidental catch estimate, effort and incidental capture data from Marine Mammal Bycatch Collectors (and Sentinel fishers, in the case of the Atlantic cod fishery) were used to calculate an estimated incidental catch rate per net-day of effort. The incidental catch rates for all trips were averaged to obtain the estimated incidental catch rate for a particular time of year, in a particular area. These estimated incidental catch rates were multiplied by fishing effort data for the entire fishery for that area and time of year to calculate a total small cetacean incidental catch estimate (Chapter 3).

Sample sizes were often small, and the residuals in the various samples were not distributed normally around the mean of each sample. The uncertainty associated with estimates of incidental capture was derived using a resampling procedure (Resampling Stats in MS Excel; Blank *et al.* 2001; Chapter 3).

4.2.4 - Age determination

Age determination in odontocetes typically involves sectioning individual teeth to count Growth Layer Groups (GLGs) in the dentine and/or cementum. GLGs consist of a single light and dark layer, which are likely caused by variation in calcium phosphate deposition in response to fluctuating environmental conditions (IWC 1980). Since odontocete teeth continue to grow throughout the animals' lives, GLGs have long been thought to represent a record of incremental growth. Each GLG has been shown to equate to a single year of life in the vast majority of species where animals of known age have been examined (Hohn *et al.* 1989; IWC 1980). In older animals, the total number of GLGs will represent the animal's minimum age, since the oldest layers at the tip of the tooth are gradually worn away by handling food items and sediment.

Teeth were extracted for age determination purposes by DFO technicians during necropsies of small cetaceans that were caught in fishing gear. Two teeth of each animal were immersed in RDO®, a commercially available decalcifying agent based on hydrochloric acid, for up to 36 hr. Subsequently, one decalcified tooth was frozen to –20 °C, mounted and cut into 20 μm-thick sections with a Leica® cryostat, according to the protocol described by Lockyer (1995). Tooth sections were cut in the longitudinal plane to obtain the broadest possible section. Sections were stained using Ehrlich's haematoxylin and aged using a binocular dissecting microscope to count the total number of GLGs. Teeth were independently aged at least twice by two experienced readers. Results from the two readers generally varied between 1-2 years, and the second decalcified tooth tooth was prepared in cases of a discrepancy of ≥2 years, or if further analysis was required.

4.3 - Results

4.3.1 - Incidental Capture Records of Small Cetaceans in 2001-2003

4.3.1.1 - Bycatch Collector Reports and Sentinel Programme Data

A total of 39, 64, and 35 reports of incidental catch of small cetaceans were received through the Bycatch Collector and Sentinel programmes in 2001, 2002, and 2003, totalling 138 records (Table 4.4). Of these, 33, 44, and 31 specimens, respectively, were collected and identified by DFO technicians (108 specimens, or an average of 81%). All were harbour porpoises, and there was no apparent deviation from a 50:50 sex ratio (53 females vs. 55 males). The remainder of the bycaught small cetaceans (6, 20, and 4 specimens in 2001, 2002 and 2003, respectively) were not collected and therefore the fisher's identification could not be independently verified. Several of these unidentified small cetaceans were probably harbour porpoises, but others may have been Atlantic white-sided dolphins (*Lagenorhynchus acutus*), whitebeaked dolphins (*L. albirostris*) or common dolphins (*Delphinus delphis*). Misidentification of small cetaceans by Bycatch Collectors and Sentinel fishers is possible, but educational materials and discussions with DFO staff have helped to minimise this problem (W. Penney, DFO-NL, pers. comm.).

Age was determined for 31, 37 and 31 harbour porpoises incidentally captured in 2001, 2002 and 2003, respectively (Table 4.6). Age structure of incidentally caught harbour porpoise did not differ substantially between males and females. In all three years, the majority of animals caught (both females and males) were under 6 years of age (74%, 51%, and 61% respectively). On average, neonates, calves and newly weaned juveniles (0-<2 years) made up approximately 14 % of the sample. The present sample of animals may be of slightly older average age than the sample used by Richardson *et al.* (Richardson 1992; Richardson *et al.* 2003), who reported a majority of animals (55.9%) being under 4 years of age. The oldest animals were 13 years of age, similar to results by Richardson *et al.* (2003), where the oldest animal was 12 years old.

An Atlantic white-sided dolphin was reported as caught in fishing gear in 2003 by a Fisheries Officer along the northwest coast of the island, in NAFO unit 4Ra (Fig. 1.4). In the same year, a white-beaked dolphin was reported stranded dead by a fisher participating in the logbook programme; incidental catch is thought to have been a factor in its death. These specimens were collected and identified by DFO technicians, but have not been used for further analyses due to the uncertainty associated with their origins.

Most of the reported bycatch events occurred in the nearshore cod gillnet fishery (73% of cases in the Bycatch Collector and Sentinel programmes for all years combined). The remainder of catches were reported by Bycatch Collectors in the nearshore fisheries for lumpfish roe (25 cases, or 18%), herring (six cases, or 4%), and Greenland halibut (three cases, or 2%), as well as the offshore fishery for monkfish and skate (three cases, or 2%). No catches were reported in fisheries for redfish or winter flounder. Most of the recorded catches (103 out of 138) occurred in July and August, whereas 34 captures were recorded in the second quarter, three took place in the fourth quarter, and none were reported in the first quarter, when there is limited fishing activity. The majority of catches involved single animals, although multiple captures of up to 4 animals (including mother-calf pairs) were occasionally reported (nine times over three years). There was considerable intra-annual variation in catch rates (number of small cetaceans/net-day) among fishers within the same area, as well as variation in catch rates from the same fishers in consecutive years. Most fishers did not capture any small cetaceans during any given period, while some caught as many as 8 animals per year. Multiple catches of small cetaceans were reported from numerous areas around Newfoundland, including Fogo Island (NAFO unit 3Ki), in Conception Bay (NAFO unit 3Lf), St. Mary's Bay (NAFO unit 3Lq) and Bay St. Georges (NAFO unit 4Rd; Figure 1.4).

4.3.1.2 - Fishery Observer Programme Data

A total of 10, 24 and 3 records of cetacean incidental catch events were made available through the Fishery Observer Programme in 2001, 2002 and 2003 respectively (Table 4.4). Bycatches were associated with the offshore monkfish and skate fishery (N=25), the nearshore cod fishery (N=10), the offshore white hake fishery (N=1) and the offshore Greenland halibut fishery (N=1). The first records of incidental catch events in the fishery for monkfish and skates occurred in 2001 (one report), and then increased dramatically in 2002 (21 reports), before dropping again in 2003 (three reports). In the nearshore cod fishery, a total of eight records were reported in 2001, two events in 2002, and none in 2003. There was a single report of small cetacean bycatch in the offshore gillnet fishery for white hake, in 2002. All these reports referred to various species of dolphins and porpoises. The incidental catch in the offshore Greenland halibut fishery involved at least one long-finned pilot whale (*Globicephala melas*), caught in 2001.

Observer coverage of nearshore fisheries was low; on average, 0.7% of landed catch in the nearshore Atlantic cod fishery was observed during the period 2001-2003 (Table 4.1). This coverage represents a smaller fraction of the fishery (based on kg landed catch) than the combined Bycatch Collector and Sentinel programmes. The only instance when Fishery Observer coverage was greater than that of Bycatch Collector and Sentinel programmes was during the first quarter, along the south coast. This might be caused by the fact that the small-boat fishers, who make up the vast majority of the combined Bycatch Collector and Sentinel datasets, may be less able to fish during the winter months due to inclement weather, whereas Fishery Observers typically work on larger vessels that are not restricted in this way.

There is considerable uncertainty regarding the number of animals involved in incidental capture events. Fishery Observers only reported the total discarded weight of the small cetaceans for each individual capture event without recording the number of animals, and this, combined with occasional uncertainty in species identification, may have led to a biased estimate of the total numbers of cetaceans caught incidentally in these fisheries. This study has attempted to minimise this bias by assuming the lowest possible number of individuals involved in any given incident (typically a single animal), by referencing total catch weights with weights reported in the literature.

4.3.2 - Current Fishing Effort and Associated Incidental Catch

4.3.2.1 - Atlantic Cod

As of 2002, approximately 2,700 vessels landed catch as part of the Atlantic cod fishery (Tables 4.1, 4.2). This included small-boat, nearshore operations as well as larger vessels capable of going further offshore. Nets used in this fishery typically have a 14 cm mesh size. In 2001 and 2002, most cod fishing effort occurred along the south and west coasts of Newfoundland; there was relatively little effort offshore. In 2003, the cod fisheries along the east/northeast and west coasts of Newfoundland were closed for conservation purposes, limiting the directed cod fishery to the Sentinel fishers in those areas. This reduced the total number of participants to 962, fishing mainly off the south coast where a commercial fishery for cod continued on a limited basis (DFO 2004; Figs. 3.1, 4.1 and 4.3). Landings were highest in July-September (third quarter) of each year, but considerable amounts were also landed in the fourth quarter (Figs. 4.2 C-D, 4.3 C-D, 4.4 C-D). Observer coverage for this fishery was relatively low – Observers recorded approximately 0.7% of nearshore landings, and 5.9% of offhore landings.

There were no reports of any incidental catches in the offshore fishery for cod off the south coast of Newfoundland. Therefore, incidental catch estimates were calculated for the nearshore fishery only, and are presented for each quarter of the year (Table 4.5). Based on recovered carcasses, all of these animals were likely harbour porpoises. The average annual incidental catch estimates were 688 animals (95 % C.I.: 102-1,715) in 2001, 1,296 animals (95% C.I.: 365-2,632) in 2002, and 2,001 animals (95% C.I.: 295-4,678) in 2003. In 2001 and 2002, the majority of estimated catches (77% and 61% respectively) occurred in July-September (third quarter) but in 2003, 73% of all estimated catches occurred in April-June (second quarter).

4.3.2.2 - Lumpfish

The lumpfish fishery is a relatively small-scale fishery, mainly prosecuted with small vessels in shallow nearshore waters on all coasts of the island. The number of participating vessels varied from 1,528 in 2001, to 811 in 2002, to 1,009 in 2003. Nets used in this fishery typically have a 25 cm mesh size. There have been substantial fluctuations in landings in recent years (Tables 4.1, 4.2; Fig. 4.5). The season for the lumpfish fishery is short when compared to other species, with the majority of catches being landed in May and June. For this reason, all landings in a given year were analysed together. Fishery Observer coverage in this fishery was low; Observers recorded approximately 1.4% of nearshore landings (Table 4.1; Fig. 4.6).

Based on collected specimens, all of whom were harbour porpoise, it is assumed that most bycaught small cetaceans in the nearshore lumpfish fishery were of this species. In 2001, the total average incidental catch estimate for the nearshore lumpfish fishery was 84 small cetaceans (95% C.I.: 2-240; Table 4.4). Bycatch Collectors did not report any incidental catch of small cetaceans in 2002, when poor catches were reported in the lumpfish fishery (Table 4.1). An independently identified specimen collected by a fisher not affiliated with the Bycatch Collector programme indicated that despite reduced fishing effort, harbour porpoises were still captured in lumpfish nets in 2002. For 2003, the average incidental catch estimate was 211 small cetaceans (95% C.I.: 20-499).

4.3.2.3 - Atlantic Herring

The nearshore gillnet fishery for Atlantic herring is practiced on a small scale in various parts of the province. The greatest concentration of participants was along the west coast of the island, particularly in NAFO unit 4Ra (the Strait of Belle Isle; Figs. 1.2, 1.4). Numbers of participating vessels varied from 207 in 2001, to 196 in 2002, to 97 in 2003. Total landed catches were variable during this time (Tables 4.1, 4.2). Nets used in this fishery typically have a 6 cm mesh size. Since western Atlantic herring reaches its northernmost distribution in Newfoundland waters, catches often vary from year to year. There are several clearly defined substocks of herring in these waters, each fished in either the spring or the fall. For this reason, data were separated by quarter. There was virtually no Fishery Observer coverage of this fishery (Tables 4.1, 4.2).

All incidental catch in this fishery occurred during July-September. Based on collected specimens, all of whom were harbour porpoise, it is assumed that the vast majority of bycaught small cetaceans in the nearshore herring fishery were of this species. In 2001, the average incidental catch estimate for the nearshore herring fishery was 89 small cetaceans (95% C.I.: 26-176; Table 4.5). Bycatch Collectors did not report any incidental catch of small cetaceans in 2002. In 2003, the total average incidental catch estimate for the nearshore herring fishery was 10 small cetaceans (95% C.I.: 0-29).

4.3.1.4 - Monkfish and Skates

The monkfish and skate fishery has been prosecuted over the last decade in offshore waters along the southern edge of the Grand Banks (NAFO Divisions 3O and 3Ps), primarily along the shelf edge between 100 and 1,000 m (DFO

2000; Tables 4.1, 4.2; Figs. 1.2, 1.3). Only larger vessels (>35 ft) participated in this fishery, using nets with a 30 cm mesh size. The number of participating vessels increased over time, with 36 vessels in 2001, 58 in 2002, and 90 vessels in 2003. Total landed catches of monkfish and skate have increased significantly in recent years (Tables 4.1, 4.2; Fig. 4.10). Incidental catch estimates were calculated for a single area (the continental shelf break in NAFO Divisions OPs). All fishing effort was concentrated in one relatively short period during the summer months; for this reason, all landings in any given year were analysed as one set of data. Fishery Observer coverage in this fishery was relatively high, with Observers recording approximately 36% of landings (Table 4.1; Fig. 4.11).

Various pelagic dolphins, as well as harbour porpoises, were reported as catch in this fishery by Fishery Observers. For 2001, the average annual incidental catch estimates for the offshore monkfish and skate fishery was found to be one small cetacean (95% C.I.: 0-4), based on net-days (Table 4.5). By 2002, these estimates had increased to an annual average of 60 small cetaceans (95% CI: 33-92), of which approximately 6 animals may have been harbour porpoises, based on the fraction of animals identified as such by Fishery Observers. In this season, 21 incidental capture events were reported, of which two were identified as harbour porpoises, six as common dolphins, six as Atlantic white-sided dolphins, and seven as unspecified dolphins or porpoises. This would imply a harbour porpoise bycatch estimate of approximately 6 animals. In

2003, annual rates of incidental catch had again declined to approximately 5 small cetaceans (95% CI: 0-12).

4.3.2.5 - White Hake

Most of the gillnet fishery for white hake occurs in offshore waters along the southern edge of the Grand Banks (NAFO Divisions 3O, 3Ps), where the species reaches its northernmost distribution (DFO 2002; Figs. 1.2, 1.4). Only larger vessels (>35 ft) participated in this fishery, although small catches were also made inshore locally by some small-boat fishers. Nets used in this fishery typically have a 14 cm mesh size. The number of participating vessels decreased from 38 vessels in 2001, to 24 in 2002, and 22 in 2003. Total landed catches have been variable during this time (Tables 4.1, 4.2; Fig. 4.12). All fishing effort was concentrated in one relatively short period during the summer months; for this reason, all landings in any given year of the offshore component of this fishery (the continental shelf break in NAFO Divisions OPs) were analysed as one set of data. No reports of incidental catch events were available for the nearshore component of this fishery. Fishery Observers recorded approximately 14% of landings (Table 4.1; Fig. 4.13).

For 2001 and 2003, no incidental catch events were reported. In 2002, the total average incidental catch estimates was 29 porpoises (not resampled; Table 4.5). This was based on one incidental catch event of harbour porpoises (Table 4.4).

4.3.2.6 - Greenland Halibut

The Greenland halibut fishery is conducted mainly in offshore waters along the edge of the Newfoundland and Labrador continental shelf between 600 and 1,400 m, with concentrations in NAFO Divisions 0B, 2J3KL, and 3O (Figs. 1.2, 1.3, 1.4). A limited nearshore fishery also takes place wherever deep waters occur close to shore, such as in NAFO units 3Ki, 3Lb, 3Psb and particularly 4Rb (Fig. 1.4). Vessels fishing offshore were all large (≥35 ft), but in the nearshore areas, smaller vessels also participated; nets typically have a 15 cm mesh size. The number of vessels ac in this fishery has fluctuated, from 317 in 2001, to 178 in 2002, and 183 in 2003. Total landed catches of Greenland halibut have declined in recent years (Tables 4.1, 4.2; Figs. 4.14, 4.16 and 4.18). Incidental catch estimates were calculated for each quarter of the year. Most fishing effort occurred in the summer months, during the second and third quarter. Fishery Observers recorded approximately 1.5% of nearshore landings, and approximately 4.4% of offshore landings (Table 4.1; Figs. 4.15, 4.17 and 4.19).

All incidental catch occurred in the second and third quarter of the year, and all reported small cetaceans were harbour porpoise. It is therefore assumed that most small cetaceans caught incidentally in this fishery were harbour porpoises. For 2001 and 2003, no incidental catch was reported in the nearshore fishery. In 2002, the total average incidental catch estimate was 29 small cetaceans (95% C.I. 0-78; Table 4.5). No small cetaceans were reported in the offshore fishery, apart from a single long-finned pilot whale that was reported caught in waters of NAFO Division 3L by a Fishery Observer in 2001.

4.3.1.7 - Redfish

The redfish gillnet fishery in Newfoundland and Labrador waters is concentrated in nearshore waters along the southwestern Grand Banks and the Laurentian channel, as well as in the Gulf of St. Lawrence (Figs. 1.2, 1.3, 1.4). Sets occurred at a depth of several hundred meters, along the shelf edge, and nets typically had a 14 cm mesh size. A total of 138 vessels were active in this fishery in 2001, 93 vessels in 2002, and 86 in 2003. Landings have remained relatively stable in recent years (Table 1; Fig. 4.20). Nearly all vessels involved in this fishery were smaller than 35 ft. Most catches were landed during the third quarter of the year. Observer coverage in this fishery was limited, with Observers recording approximately 1.5% of nearshore landings (Table 4.1; Fig. 4.21). No incidental catch of small cetaceans was recorded in this fishery between 2001-2003.

4.3.1.8 - Winter Flounder

The gillnet fishery for winter flounder in Newfoundland and Labrador is conducted almost exclusively in nearshore waters, particularly along the northeast and south coasts. 227 Vessels participated in this fishery in 2001, 178 in 2002, and 261 in 2003. Landings of winter flounder have decreased in recent years (Table 1; Fig. 4.22). Most catches were landed in the third quarter. The vast majority of vessels were smaller than 35 ft, and nets typically had a mesh size between 16.5 cm and 20.5 cm. Observer coverage in this fishery was limited, with Observers recording approximately 0.5% of nearshore landings (Table 4.1; Fig. 4.23). No incidental catch of small cetaceans was recorded in this fishery between 2001-2003.

4.4 - Discussion

4.4.1 - Estimated Small Cetacean Incidental Catch In 2001-2003

Based on data presented here, annual mean incidental catch estimates of small cetaceans, the majority of whom are likely harbour porpoises, in Newfoundland fisheries were approximately 1,516 animals per year, with the vast majority of these occurring in nearshore fisheries around the island of Newfoundland. By comparison, the last incidental catch estimate for harbour porpoises was 2,242 porpoises in all of Newfoundland a decade earlier (DFO 2001; Lien 2001). The confidence limits around the present estimates are large, so it is difficult to determine if these estimates represent a decline or increase in porpoise incidental catch since the onset of the moratoria. The wide confidence intervals are indicative of the variability associated with incidental catches of small cetaceans. Such events occur only during a minority of fishing trips, and this results in a resampling of a dataset composed primarily of zeroes with a few catch rates greater than zero, determined by the amount of net-day effort and number of animals involved. While the number of nets that fishers can use is limited by their license conditions, the soak time can vary considerably due to weather conditions and other logistical factors, leading to a wide range of incidental catch rates (expressed as number of small cetaceans per net-day). This accounts for the wide confidence intervals observed in various incidental catch estimates. Further complicating such comparisons is the fact that Fishery Observer coverage rates are very low or non-existent for fisheries which have the potential to be sources of incidental catch mortality for harbour porpoises, such as the nearshore lumpfish or herring fisheries.

There may be several reasons why there is such variation in incidental catch reported among fishers, with some fishers having larger harbour porpoise catches than others. Perhaps some fishers are operating in harbour porpoise "hotspots" where there is an overlap of harbour porpoise and their prey, or simply areas of higher harbour porpoise density. When the number of net-days required to land a certain weight of cod by those fishers that reported small cetacean incidental catch were compared with those that did not, it was found that there was no greater effort required to land cod when small cetaceans were also caught (Lawson *et al.* 2004; Fig. 4.24). This suggests that the larger catches of small cetaceans by these fishers may not be simply due to these cetaceans chasing the same prey as the cod, in the same area. There were not enough data in this study to provide strong evidence of "hotspots" around the island of Newfoundland, although there is a suggestion of this for the Fogo Island area (NAFO unit 3Ki), Conception Bay (NAFO unit 3Lf), St. Mary's Bay (NAFO unit 3Lq), Placentia Bay (NAFO unit 3Psc), and the Strait of Belle Isle (NAFO unit 4Ra), based on the repeated occurrence of captured porpoises in these areas (Fig. 1.4). If such data were available, it might assist in interpreting these results if one could stratify the study area according to harbour porpoise density. In this way, the possible relationship between porpoise abundance and incidental catch rates, as well as the potential influence of other factors such as prey abundance and distribution, could be further explored. Harbour porpoises are known to use oceanographic features such as fronts and island wakes while foraging, and a detailed analysis of where these features co-occur with gillnet fisheries, taking into account the geographical location of incidental catch reports, might allow the identification of harbour porpoise 'high-risk zones' in Newfoundland and Labrador (Johnston *et al.* 2005).

The distribution of catch reports appears to confirm the suggestion that harbour porpoise are present seasonally in waters around the island of Newfoundland (Fig. 4.25). Porpoises are captured from May-October, initially in the lumpfish fishery, and subsequently also in other fisheries such as the cod fishery. Frequency of catches appeared to change from coast to coast: there were no catch reports available from the south coast after August despite continued fishing activity, but catches were reported along both the northeast and west coasts of the island through September and into October. It is possible that harbour porpoises along the south coast of Newfoundland are more migratory than porpoises along the other coasts, and leave for presumed wintering grounds off the eastern coast of the United States at an earlier date. Alternatively, porpoises could move into nearshore waters along the south coast during early summer, and then move northward on both sides of Newfoundland as the season progresses, possibly in search of food. Further research is required to determine how harbour porpoises use the nearshore environment around Newfoundland throughout the year.

It is presently unknown how the fisheries for monkfish, skates and white hake capture pelagic dolphins, since these species are not generally considered to be benthic foragers. Dolphins may be attracted to sounds of gillnets being set and hauled, as well as to bright lights when fishing at night, potentially leading to entanglement as the gear is being deployed or hauled in (Tregenza *et al.* 1997). Further research is required to test this hypothesis. It is also unclear why the incidental catch estimates in the monkfish fishery are so variable. There is no evidence for a redistribution of fishing effort over this period. Possible reasons might include an influx of pelagic dolphins in response to temporarily favourable conditions in 2002, or increased focus among some observers on documenting small cetacean incidental catch. Both common and Atlantic white-sided dolphins are known to range widely over large areas, and their occurrence is strongly linked to patchily-distributed pelagic food resources (National Audubon Society 2002; NMFS 2005a, 2005b). Stochastic fluctuations in prey availability may have lead to a periodically higher abundance of these species in areas targeted by the monkfish and skate fishery in 2002.

4.4.2 - Potential Difficulties with Fishery Observer Data

Several difficulties were noted when using data from the Newfoundland and Labrador Fishery Observer programme to estimate incidental catch of small cetaceans. Coverage is limited or absent in several nearshore fisheries, largely due to lack of financial resources for the Observer programme. The Fishery Observer programme is set up to adequately sample levels of incidental catch of fish species, but these coverage levels are insufficient to reliably record catch of relatively rare species such as harbour porpoise. This requires a high level of observer coverage that can only be achieved through considerable investment in manpower (Babcock *et al.* 2003). Bycatch Collector data may be used to describe incidental catch in these fisheries, but that database also suffers from lack of coverage in some fisheries that may capture seabirds (e.g. nearshore gillnet fishery for Atlantic herring). An expansion of the Bycatch Collector programme to include more fishers active in these fisheries is desirable.

Although Observers record incidental catches of marine mammals and other species of large marine vertebrates, this is not their core activity, and the data collected in this manner may be biased in various ways. Observers receive intensive, DFO-administered training in identification of fish species, in line with their core responsibilities of identifying incidental catch of species under moratorium, but are also trained in identifying marine mammals and other species by representatives of the Marine Mammal Section (DFO-NL). However, it is possible that not all Observers receive sufficient training to correctly identify incidentally caught marine mammals down to species level. This is problematic with regard to identification of small cetaceans such as dolphins and harbour porpoise, which may look similar to the untrained observer. Because incidental catch of marine mammals remains a relatively rare event, there may be little opportunity for observers to become familiar with these species. Possibly as a result of this, several Observer records are of "Unidentified dolphin" or "Porpoises (Phocoenidae)". Some observers may be diligent in reporting additional species, while others may be less inclined to do so. Also, Observer records of incidental catch events of comparatively rare species such as small cetaceans are typically not checked for accuracy once their reports have been sent in. In such a situation, cases of misidentification may go unnoticed (D. Kulka, DFO-NL, pers. comm.). This problem appears to be caused by a lack of resources at the level of the Observer Programme. Mechanisms to independently assess the reliability and validity of identifications are urgently required. In addition, having Observers record the estimated number of individuals involved would enhance the utility of the Fishery Observer data for monitoring incidental catch of small cetaceans.

4.5 - Conclusions

The current best average estimate of incidental catch of small cetaceans in nearshore gillnet fisheries in Newfoundland waters is approximately 1,516 animals per year, based on analysis of three years of data on various nearshore and offshore gillnet fisheries between 2001 and 2003, although confidence itnervals are considerable. Most of these animals are thought to be harbour porpoise, based on recovered identified specimens. The nearshore fishery for Atlantic cod appears to be the major source of incidental mortality, despite reductions in fishing effort since widespread fisheries closures in the early 1990s. Smaller numbers of harbour porpoises were reported as incidental catch in other nearshore gillnet fisheries. Catches of several species of small cetaceans, including harbour porpoises, have been reported in offshore fisheries for monkfish, skates and white hake. Average annual incidental catch estimates for these fisheries range in the low to high tens of small cetaceans, although interannual variability is large. The available data did not permit the identification of areas where incidental catch is more prevalent. Conclusions on the sustainability of this incidental mortality in the longer term will require increased understanding of harbour porpoise abundance and population structure in Newfoundland and Labrador.

4.6 – References

Aguilar, A. and A. Borrell. 1995. Pollution and harbour porpoises in the eastern North Atlantic: a review. Reports of the International Whaling Commission 16 (Special Issue): 231-242.

Anonymous. 1998. Report of the Working Group on marine mammal population dynamics and trophic interactions. ICES CM 1998/G: 6 pp.

Anonymous. 1999. Report of the Working Group on marine mammal population dynamics and trophic interactions. ICES CM 1999/G: 3 pp.

Babcock, E.A., E.K. Pikitch and C.G. Hudson. 2003. How much observer coverage is enough to accurately estimate bycatch? Oceana and Pew Institute for Ocean Science, 36 pp. Available online at: http://www.-pewtrusts.com/pdf/oceana_bycatch_110403.pdf.

Barlow, J. and D. Hanan. 1995. An assessment of the status of the harbour porpoise in central California. Report of the International Whaling Commission 16 (Special Issue): 123-140.

Berggren, P., P.R. Wade, J. Carlström and A.J. Read. 2002. Potential limits to anthropogenic mortality for harbour porpoise in the Baltic region. Biological Conservation 103: 313-322.

Bjørge, A., R.L Brownell Jr., G.P. Donovan, and W.F. Perrin. 1994. Significant directed and incidental catches of small cetaceans. A report by the Scientific Committee on the International Whaling Commission to the United Nations conference on environment and development (UNCED). Report of the International Whaling Commission 15 (Special Issue):73-130.

Blank, S., C. Seiter, and P. Bruce. 2001. Resampling stats in Excel. Version 2. Resampling Stats, Inc., Arlington VA. 172 p.

Brodie, P.F. 1995. The Bay of Fundy/Gulf of Maine harbour porpoise (*Phocoena phocoena*): some considerations regarding species interactions, energetics, density dependence and bycatch. Report of the International Whaling Commission 16 (Special Issue):181-187.

Caswell, W., S. Brault, A.J. Read and T.D. Smith. 1998. Harbor porpoise and fisheries: an uncertainty analysis of incidental mortality. Ecological Applications 8(4): 1226-1238.

CEC [Commission of the European Communities]. 2002. Incidental catches of small cetaceans. Report of the Subgroup on Fisheries and Environment (SGFEN) of the Scientific, Technical and Economic Committee for Fisheries (STECF) Commission Staff Working Paper, Brussels. SEC 2002:376: 83 pp.

Christensen, O. and W.H. Lear. 1977. Bycatches in salmon drift-nets at west Greenland in 1972. Kommissionen for Videnskabelige Undersøgelser i Grønland 205 (5): 5-37.

COSEWIC. 2003a. COSEWIC assessment and update status report on the harbour porpoise *Phocoena phocoena* (Northwest Atlantic population) in Canada. Committee on the Status of Endangered Wildlife in Canada. vii + 30 pp. Available online at: http://www.sararegistry.gc.ca/virtual_sara/-files/cosewic/sr_harbour_porpoise_e.pdf.

COSEWIC. 2003b List of Canadian species at risk, April 2003. Committee on the Status of Endangered Wildlife in Canada: 25 pp.

DFO [Department of Fisheries and Oceans]. 2000. Monkfish in Divisions 3L, 3N, 3O and Subdivision 3Ps. 4 p. DFO Science Stock Status Report A2-20. Available online at: http://www.dfo-mpo.gc.ca/CSAS/CSAS/status/-2000/a2-20e.pdf.

DFO [Department of Fisheries and Oceans]. 2001. Proceedings of the International Harbour Porpoise Workshop. Canadian Science Advisory Secretariat, Proceedings Series 2001/42; 47 pp. Available online at: www.dfo-mpo.gc.ca/csas/Csas/English/Publications/Proceedings_e.htm.

DFO [Department of Fisheries and Oceans]. 2002. White hake in Division 3L, 3N, 3O, and Subdivision 3Ps. DFO Canadian Science Advisory Secretariat Stock Status Report A2-06: 5 pp. Available online at: http://www.dfo-mpo.gc.ca/csas/Csas/status/2002/SSR2002_A2-06e.pdf.

DFO [Department of Fisheries and Oceans]. 2004. Subdivision 3Ps Cod. DFO Scientific Advisory Secretariat Stock Status Report 2004/039: 15 pp. Available online at: www.dfo-mpo.gc.ca/CSAS/CSAS/status/2004/-SSR2004_039_E.pdf.

Donovan, G.P. and A. Bjørge. 1995. Harbour porpoises in the North Atlantic: edited extract from the report of the IWC Scientific Committee. Report of the International Whaling Commission 16 (Special Issue): 3-25.

Efron, B., and R.J. Tibshirani. 1993. An Introduction to the Bootstrap. Monographs on Statistics and Applied Probability 57, Chapman & Hall, N.Y., USA: 436 pp.

Gaskin, D.E. 1984. The harbour porpoise *Phocoena phocoena* (L.): regional populations, status, and information on direct and indirect catches. Report of the International Whaling Commission 34:569-586.

Hutchinson, J. 1996. Fisheries Interactions: The harbour porpoise-a review. Pages 129-165 in M.P. Simmonds and J.D. Hutchinson (eds.): The Conservation of Whales and Dolphins. Science and Practise. John Wiley and Sons, Chichester, UK.

IWC [International Whaling Commission]. 1980. Report of the Workshop 'Growth of Odontocetes and Sirenians: Problems in Age Determination'. Proceedings of the International Conference on Determining Age of Odontocete Cetaceans [and Sirenians]. Report of the International Whaling Commission 3 (Special Issue): 1-50.

IWC [International Whaling Commission]. 1994. Report of the Workshop on Mortality of cetaceans in passive fishing nets and traps. Report of the International Whaling Commission 15 (Special Issue):1-71.

IWC [International Whaling Commission]. 2000. Annex 1: Report of the Sub-Committee on Small Cetaceans. Journal of Cetacean Research and Management 2 (Supplement): 235-263.
Jefferson, T.A. and B.E. Curry. 1994. A global review of porpoise (Cetacea, Phocoenidae) mortality in gillnets. Biological Conservation 67 (2): 167-183.
Johnston, D.W., A.J. Westgate, and A.J. Read. 2005. Effects of fine-scale oceanographic features on the distribution and movements of harbour porpoises *Phocoena phocoena* in the Bay of Fundy. Marine Ecology Progress Series 295: 279-293.
Klinowska, M. 1991. Dolphins, porpoises and whales of the world: The IUCN Red Data Book. IUCN, Gland, Switzerland and Cambridge, UK.
Koschinski, S. 2002. Current knowledge of harbour porpoises (*Phocoena phocoena*) in the Baltic Sea. Ophelia 55 (3): 167-197.
Kulka, D.W., C.M. Miri and J.R. Firth. 2000. Observer Programme Training Manual - Newfoundland Region. A Science Manual for the 2000 Observer Programme Tranining Course, Department of Fisheries and Oceans (DFO), St. John's, Newfoundland, Canada: 206 pp.
Larrivée, M.-L. 1996. Étude des prises accidentelles de marsouins communs, *Phocoena phocoena*, dans les filets maillants pour la région de gulfe et de l'estuaire de Saint-Laurent (Canada). M.Sc. Thesis, Laval University, Quebec City, QC, Canada.
Lawson, J., S. Benjamins, and G. Stenson. 2004. Harbour porpoise bycatch estimates for Newfoundland's 2002 nearshore Cod fishery. DFO Scientific Advisory Secretariat Research Document 2004/066: 32 p. Available online at: www.dfo-mpo.gc.ca/csas/Csas/DocREC/2004/RES2004_066_E.pdf.
Lesage, V., J. Keays, S. Turgeon, and S. Hurtubise. 2004. Incidental catches of harbour porpoises (*Phocoena phocoena*) in the gillnet fishery of the Estuary and Gulf of St. Lawrence in 2000-2002. Canadian Technical Report on Fisheries and Aquatic Science 2552: 37 pp.
Lien, J. 2001. Incidental bycatch of harbour porpoise in Newfoundland and Labrador-as we know it. Paper presented at the Department of Fisheries and Oceans' International Harbour Porpoise Workshop, Dartmouth, NS, Canada, 26-28 March 2001: 12 pp.
Lien, J., G.B. Stenson, and I.H. Ni. 1988. A review of incidental entrapments of seabirds, seals and whales in nearshore fishing gear in Newfoundland and Labrador: A problem for fishers and fishing gear designers. Proceedings World Symposium on fishing Gear and Fishing Vessel Design. St. John's, NL, Canada: 67-71.
Lien, J., G.B. Stenson, S. Carver, and J. Chardine. 1994. How many did you catch? The effect of methodology on bycatch reports obtained from fishers. Report of the International Whaling Commission 15 (Special Issue): 535-50.

Lockyer, C. 1995. A review of factors involved in zonation in odontocete teeth, and an investigation of the likely impact of environmental factors and major life events on harbour porpoise tooth structure. Report of the International Whaling Commission 16 (Special Issue): 511-529.

Northridge, S.P. and R.J. Hofman. 1999. Marine Mammal Interactions with Fisheries. Pages 99-119 in J.R. Twiss Jr. and R.R. Reeves (eds.): Conservation and management of marine mammals. Smithsonian Institution Press, Washington, D.C., USA.

Read, A.J. 1994. Interactions between cetaceans and gillnet and trap fisheries in the Northwest Atlantic. Reports of the International Whaling Commission 15 (Special Issue): 133-149.

Read, A.J. and D.E. Gaskin. 1988. Incidental catch of harbour porpoises by gill nets. Journal of Wildlife Management 52: 517-523.

Richardson, S.F. 1992. Growth and reproduction of the harbour porpoise, *Phocoena phocoena* (L.), from eastern Newfoundland. Department of Biology, Memorial University of Newfoundland, St. John's, NL, 102 pp.

Richardson, S.F., G.B. Stenson and C. Hood. 2003. Growth of the harbour porpoise (*Phocoena phocoena*) in eastern Newfoundland, Canada. NAMMCO Scientific Publications 5: 211-222.

Rosel, P.E., S.C. France, J.Y. Wang and T.D. Kocher. 1999. Genetic structure of harbour porpoise *Phocoena phocoena* populations in the northwest Atlantic based on mitochondrial and nuclear markers. Molecular Ecology 8: S41-S54.

Rossman, M.C. and R.L. Merrick. 1999. Harbor porpoise bycatch in the Northeast multispecies sink gillnet fishery and the mid-Atlantic coastal gillnet fishery in 1998 and during January-May 1999. Northeast Fisheries Science Center Reference Document 99-17. 36 p. [Available from National Marine Fisheries Service, 166 Water Street, Woods Hole MA USA 02543-1026.]

Simon, J.L. 1997. Resampling: The New Statistics. Resampling Stats, Inc., Arlington VA. 436 p.

Smith, T., D. Palka, and K. Bisack. 1993. Biological significance of bycatch of harbor porpoise in the Gulf of Maine demersal gillnet fishery. Northeast Fisheries Science Center Report 93-23: 15 pp.

Stenson, G.B. 2003. Harbour porpoise (*Phocoena phocoena*) in the North Atlantic: Abundance, removals, and sustainability of removals. Pages 271-302 in T. Haug, G. Desportes, G.A. Víkingsson and L. Witting (eds.): Harbour porpoises in the North Atlantic. NAMMCO Scientific Publications Volume 5, The North Atlantic Marine Mammal Commission, Tromsø, Norway.

Teilmann, J. and N. Lowry. 1996. Status of the harbour porpoise (*Phocoena phocoena*) in Danish waters. Report of the International Whaling Commission 46: 619-625.

Tregenza, N.J.C., S.D. Berrow, P.S. Hammond and R. Leaper. 1997. Harbor porpoise (*Phocoena phocoena* L.) by-catch in set gillnets in the Celtic sea. ICES Journal of Marine Science 54: 896-904.

Trippel, E.A. and T.D. Shepherd. 2004. By-catch of harbour porpoise (*Phocoena phocoena*) in the Lower Bay of Fundy gillnet fishery, 1998-2001. Canadian Technical Report of Fisheries and Aquatic Sciences 2521: iv + 33 pp.

Trippel, E.A., M.B. Strong, C.C. Hood, C. Richter, and J. Lien. 1996. By-catch of harbour porpoise (*Phocoena phocoena*) in the Lower Bay of Fundy gillnet fishery in 1995. DFO Atlantic Fisheries Research Document 96/110.

Trippel, E.A., M.B. Strong, J.M. Terhune and J.D. Conway. 1999. Mitigation of harbour porpoise (*Phocoena phocoena*) by-catch in the gillnet fishery in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 56 (1): 113-123.

Vinther, M. 1999. Bycatches of harbour porpoises (*Phocoena phocoena* L.) in Danish set-net fisheries. Journal of Cetacean Research and Management 1 (2): 123-135.

Waring, G.T., J.M. Quintal, and S.S. Swartz (eds). 2001. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments-2001. NOAA Technical Memorandum NMFS-NE-168: 307 pp.

CHAPTER 5 - INCIDENTAL CATCH ESTIMATES OF SEALS IN NEWFOUNDLAND AND LABRADOR GILLNET FISHERIES, 2001-2003

5.1 - Introduction

5.1.1 - An Overview of Pinniped Incidental Catch in Fisheries

Incidental catch of pinnipeds in fishing gear is thought to cause considerable incidental mortality in some areas, and has led to declines or local extinctions of some species (Wickens 1995). Each year, hundreds of thousands of pinnipeds worldwide become entangled in gillnets, get hooked on longlines, or caught in trawls (Christensen and Lear 1977; Lien *et al.* 1987; Woodley and Lavigne 1991; Harcourt *et al.* 1994; Pemberton *et al.* 1994; Wickens 1995; Berrow *et al.* 1998; Morizur *et al.* 1999; Manly *et al.* 2002; Carretta *et al.* 2004; Tudela 2004; Read *et al.* 2006). Pinnipeds display life history traits characteristic of large-bodied predators, in that they are long-lived, take several years to mature, and produce a single young per year. These traits make pinniped populations vulnerable to anthropogenic mortality, such as entanglement in fishing gear, which may lead to rapid declines in population size (Wickens 1995; Lewison *et al.* 2004). Pinnipeds are also impacted by other anthropogenic stressors, such as direct hunting, pollution, disturbance of haul-out sites, and climate change, which may negatively affect their populations (DFO 2000, 2003; Bowering and Atkinson 2003; Waring *et al.* 2003; Kakuschke *et al.* 2005; Shaw *et al.* 2005). Incidental catch of pinnipeds in fishing gear is a potential conservation concern. Consistent monitoring of incidental catch of seals can help assess the impacts of this mortality, but is often difficult to achieve. Many observer programmes focus on catches of commercially valuable fish species, and observers may not have the time, training, or inclination to report incidental catches of seals. Despite these problems, observer data can be used to generate minimum estimates of incidental catches for these species (Wickens 1995).

In this chapter, incidental catch estimates of seals in Newfoundland and Labrador gillnet fisheries will be calculated, based on the methodology outlined in Chapters 3 and 4. Possible sources of variation among these incidental catch estimates will also be discussed. The mortality estimates can be put in the context of the population estimates of each species, where available, to determine the possible effect of these catches on the populations of the different seal species. If no population estimates are available, the context will be provided qualitatively.

5.1.2 - Pinnipeds of Newfoundland and Labrador

Coastal waters of the island of Newfoundland are seasonally frequented by six species of pinnipeds, all of which are phocid seals (Bowering and Atkinson 2003). These include harp seals (*Pagophilus groenlandicus* Erxleben) and hooded seals (*Crystophora cristata* Erxleben), both of which breed on sea ice in offshore Newfoundland waters and range widely around the island; harbour seals (*Phoca vitulina concolor* L.) and grey seals (*Halichoerus grypus* Fabricius), which occur locally around the island, particularly along the southern and western coasts; and ringed seals (*Pusa hispida* Schreber) and bearded seals (*Erignathus barbatus* Erxleben), which are relatively uncommon winter visitors to the northern tip of the island and the coasts of Labrador. Historically, the Atlantic walrus (*Odobenus rosmarus rosmarus* L.) occurred in Atlantic Canadian waters, but was extirpated through hunting; it is now only rarely recorded as a vagrant (Kingsley 1998; Dyke *et al.* 1999).

Harp seals are by far the most abundant species of seal in most areas of the province, with a current estimated population of 5.9 million seals (DFO 2005). During the breeding season in March-April, the species congregates in several localized patches on sea ice in the Gulf of St. Lawrence and off the northwest coast of Newfoundland, where breeding and molting take place. Subsequently, seals disperse from the patches in a generally northward migration toward Greenland and Arctic Canadian waters (Lavigne and Kovacs 1988; Sergeant

1991). Seals leaving the Gulf of St. Lawrence may follow the southern coast of Newfoundland toward the Grand Banks, or exit through the Strait of Belle Isle in the north (Fig. 1.2). These movements may bring large groups of seals close to shore. Little is known about harp seal distribution in the open ocean, although use of satellite dataloggers in recent years has begun to clarify this issue (G. Stenson, DFO-NL, unpublished data).

Hooded seals are distributed in similar areas as harp seals in Newfoundland and Labrador waters, although they are not as abundant and typically do not come close to shore (National Audubon Society 2002). Based on survey effort in 1990-1991, the total abundance at the time was estimated at 450,000-470,000 animals (DFO 2003). Current abundance is unknown, although a survey was conducted in 2005 (G. Stenson, DFO-NL, pers. comm.). Little information on hooded seal distribution at sea is available, but seals are thought to disperse offshore along the continental shelf edge in Canadian, Greenland and Icelandic waters (Bowering and Atkinson 2003).

Harbour seals occur locally in nearshore waters throughout most of the province (Sjare *et al.* 2005). Little is known about the distribution of this species in Newfoundland and Labrador waters due to lack of widespread survey effort, and no current reliable abundance estimates are available. There are thought to be several thousand harbour seals in Newfoundland waters, based on historical data (Hammill and Stenson 2000). In addition, preliminary survey data collected in 2001-2003 revealed that harbour seals continue to frequent several well-known haulout sites, and that their abundance at these sites has increased or at least remained stable since the last major study of harbour seals in Newfoundland in 1979 (Boulva and McLaren 1979; Sjare *et al.* 2005).

Little is known about the distribution or abundance of grey seals in Newfoundland waters, primarily due to lack of survey effort. Grey seals do not appear to breed in large numbers in Newfoundland, but significant colonies exist south of the province on Sable Island, N.S., and in the Gulf of St. Lawrence (Hammill *et al.* 1998; Robillard *et al.* 2005), and grey seals summer on the French island of Micquelon, just off the south coast of Newfoundland (Hammill 2005). In Atlantic Canada, the total estimated abundance of grey seals in 2004 was greater than 250,000, up from 195,000 in 1997 (DFO 2003; Hammill 2005; Trzcinsky *et al.* 2005). Some grey seals haul out in areas that are also frequented by harbour seals, potentially complicating abundance assessments (Sjare *et al.* 2005).

Ringed seals and bearded seals are uncommon winter visitors to coastal waters of northern Newfoundland (Gosselin and Boily 1994; Cleator 1996; Reeves 1998). No abundance estimates for these species are currently available for the area, although ringed seals are considered to be more abundant than bearded seals (Bowering and Atkinson 2003). In Newfoundland waters, numbers of these species are variable, which is considered to be due to their close association with sea ice, which varies from year to year.

Incidental catch of seals in fishing gear has occurred for many years in Newfoundland and Labrador, and anecdotal evidence suggests that catch rates can be high (Lien *et al.* 1989). However, only limited effort has been put into assessing this incidental catch, and there are few reliable estimates (Piatt and Nettleship 1987; Walsh *et al.* 2000). Seals have been reported caught in various types of fishing gear such as trawls, longlines and crab pots, but most appear to be caught in gillnets (DFO Fishery Observer data; Walsh *et al.* 2000). The nearshore fisheries for Atlantic cod (*Gadus morhua*) and lumpfish (*Cyclopterus lumpus*) appear to account for the majority of incidental catch records. Piatt and Nettleship (1987) recorded incidental catch of seals in nearshore gillnet fisheries during the 1981-84 fishing seasons near seabird colonies, as part of an investigation into incidental catch of seabirds (see also Chapter 6). They reported an average annual catch of 746 harp seals, 29 harbour seals, and very small numbers (<10) of hooded seals. At the time, most seals were reported caught in the nearshore cod fishery. In 1992, significant declines in cod stocks forced the closure of most fisheries targeting cod and other associated fish species, leading to a substantial reduction in overall fishing effort and the removal of large numbers of nets. The subsequent reduction in numbers of cod gillnets is thought to have led to a decrease in the numbers of seals captured. However, high levels of fishing effort in the lumpfish fishery are responsible for most incidental catches of seals (Walsh *et al.* 2000). Catch estimates in this fishery over the last 35 years have been variable, with estimated total catches of as many as 45,000 harp seals in 1994. In recent years, catches have declined to several thousand seals per year in this fishery (Sjare *et al.* 2005). No other current information is available on incidental catch of other seal species in Newfoundland and Labrador.

5.2 – Methods

Fisheries and methodologies used to estimate incidental catch were described in detail in Chapters 1, 3 and 4. Incidental catch estimation analyses were performed using trips per fisher as sampling units, using net-days as measure of effort, at the geographic scale of coastlines, because it is unlikely that seals either restrict themselves to a single NAFO unit or are distributed uniformly around the island of Newfoundland. Only limited Fishery Observer data were available for NAFO Division 4R.

5.2.1 - Identification of Seals

Some uncertainty exists with regard to the correct identification of some seals by fishers. This problem is particularly acute for harbour seals and to a far lesser extent for ringed seals, which may resemble juvenile harp seals (known locally as "beaters" or "spotted harps") that also have spotted coats. However, it is assumed that Newfoundland fishers are at least somewhat familiar with the various seal species, due to the fact that some species of seals are more likely to come ashore to rest and breed, which increases their visibility; the annual harp seal hunt, in which many fishers also participate; and the potential for depredation by seals on fish in fishing gear. In addition, all fishers participating in the Bycatch Collection programme were presented with various identification materials during interviews, which, it was hoped, improved their ability to correctly identify different seal species. In the present analysis, all "unknown" seals were considered harp seals, because of the seasonal abundance of this species in many parts of the province during times of greatest gillnet fishing effort. Nevertheless, this may have resulted in an overestimation of the incidental catches of harp seals and a complementary, negative bias in the incidental catch estimates of harbour and ringed seals.

5.3 - Results

5.3.1 - The Nearshore and Offshore Cod Fishery

Bycatch Collectors reported 37, 29 and 6 seals caught in gillnets fishing for cod nearshore during 2001, 2002 and 2003, respectively (Table 5.1). Most

(44, or approximately 61%) were identified as harp seals by fishers, while an additional 22 (31%) were not identified; many of these were likely also harp seals. There was no clear indication of segregation according to age category among recorded harp seals. Most of these seals (10, 29 and 6, respectively) were caught along the south coast, although 14 were caught in the 4^{th} quarter of 2001 along the northeast coast. Catches in 2003 were lower than earlier years due to widespread fisheries closures along the northeast and west coasts (Chapter 1). Incidental catch estimates varied from 3,234 (no 95% C.I. available) in 2001, to 1,218 (95% C.I.: 345-2,279) in 2002, to 364 (95% C.I.: 0-1,002) in 2003, leading to a total catch estimate of 4,815 harp seals (no overall 95% C.I. available) in the nearshore cod gillnet fishery around the island of Newfoundland during 2001-2003 (Table 5.3).

Harbour seals and hooded seals were also reported in the nearshore cod fishery (4 and 2 individuals, respectively, all in 2001). Approximately 90 hooded seals (95% C.I.: 0-273) and 115 harbour seals (95% C.I.: 0-319) were estimated to have been captured in this fishery during 2001 (Table 5.3). There were no records of these species from other years.

Fishery Observers recorded 5, 8 and 1 captures of seals in this fishery during 2001, 2002 and 2003, respectively, including 7 harp seals, 1 harbour seal and 6 unknown seals, which were assumed to be harp seals (Table 5.2). All 13 nearshore incidental catch records originated from the south and west coasts, and most (12) were caught during the first and fourth quarter. Harp seal incidental catch estimates varied from 448 (95% C.I.: 0-1,121) in 2001, to 425 (95% C.I.: 120-837) in 2002, to 43 (95% C.I.: 0-134) in 2003. Also, 143 harbour seals (95% C.I.: 0-445) were captured in 2001 (Table 5.4). In the offshore 3OPs cod gillnet fishery, a single harp seal was captured in 2002, leading to an estimate of 55 harp seals (95% C.I.: 0-169; Table 5.4). No records were available for 2001 or 2003.

5.3.2 - The Nearshore Lumpfish Fishery

The lumpfish fishery has been known to regularly catch large numbers of harp seals (Walsh *et al.* 2000). The main reason for this is the timing of the fishery, which takes place from late April to June, during the main northward migration of the harp seals away from the breeding and molting patches.

Bycatch Collectors reported a total of 522, 130 and 115 harp seals in lumpfish gillnets in nearshore waters in 2001, 2002 and 2003, respectively (Table 5.1). These seals represented approximately 94% of all seals reported (552, 141 and 121 reports). Approximately 80% of identified harp seals were juveniles, in line with previous reports (Walsh *et al.* 2000). An estimated 23,379 (95% C.I.: 14,983-33,078) seals were caught in 2001, 9,342 (no confidence interval available) in 2002, and 9,321 (95% C.I.: 2,226-19,294) in 2003, leading to a total estimate of 42,042 harp seals caught during 2001-2003 (no overall confidence interval available; Table 5.3). Harp seals were captured around the entire island, however a particularly large number of seals were captured along the west coast in 2001 (393 seals, or 75% of that year's reports). Bycatch Collectors frequently reported catching >10 seals per trip in this year.

Bycatch Collectors also reported other species of seals in lumpfish gillnets, including harbour seals (4 and 1 individuals in 2001 and 2002, or a total of <1%), grey seals (4 individuals in 2001, or <1%), hooded seals (9 and 1 individuals in 2001 and 2002, or 1%), ringed seals (5, 7 and 6 individuals, or 2%) and bearded seals (6 and 2 individuals in 2001 and 2002, or 1%; Table 5.1). Incidental catch estimates for harbour seals varied from 622 (95% C.I.: 0-1,696) in 2001, to 8 (95% C.I.: 0-24) in 2002, to zero in 2003. The vast majority of these catches occurred along the south coast. An estimated 273 grey seals (95% C.I.: 0-794) were caught in 2001 along the south coast. Hooded seals were captured along south and west coasts in 2001 (322 seals 95% C.I.: 15-887), and along the northeast coast in 2002 (424 seals, 95% C.I.: 0-1,283). Ringed seals were caught almost exclusively along the northenmost part of the northeast coast, leading to a total estimate of 430 (95% C.I.: 79-859) in 2001, 336 (95% C.I.: 78-672) in 2002, and 1,077 (95% C.I.: 126-2,531) in 2003. Bearded seals displayed a similar distribution in the northernmost parts of the northeast and west coasts, with catch estimates of 190 (95% C.I.: 0-516) in 2001 and 13 (95% C.I.: 0-33) in 2002 (Table 5.3).

According to Fishery Observer data for the same fishery, harp seals were caught in all years (1, 3 and 6 in 2001, 2002 and 2003, respectively; Table 5.2), leading to an estimated total of 119 (95% C.I.: 0-378), 250 (95% C.I.: 0-500) and 182 (95% C.I.: 61-337) harp seals caught in 2001, 2002 and 2003 (Table 5.4). Harbour seals were captured in 2001 and 2003 (7 and 2 specimens, respectively), leading to catch estimates of 629 (95% C.I.: 181-1,088) seals in 2001 and 61 (95% C.I.: 0-153) seals in 2003. Hooded seals were only captured in 2002 (3 specimens), leading to an estimated catch of 249 hooded seals (95% C.I.: 0-500) for that year. A single grey seal was captured in 2003, leading to an estimated catch of 32 grey seals (95% C.I.: 0-92) caught in that year (Table 5.4).

5.3.3 - The Nearshore Herring Fishery

Bycatch Collectors reported 2 harp seals and 6 hooded seals caught in 2001, leading to an incidental catch estimate of 168 harp seals and 713 hooded seals in 2001 (no 95% C.I. available for either species). No seals were reported as incidental catch during 2002 and 2003 (Table 5.1, 5.3).

5.3.4 - The Offshore Monkfish and Skate Fishery

Fishery Observers recorded small numbers of harp seals, harbour seals and grey seals in this fishery (Table 5.2). Based on these numbers, the monkfish and skate fishery captured an estimated 18 (95% C.I.: 4-35) harp seals in 2001, 23 (95% C.I.: 3-48) harp seals in 2002, and 10 (95% C.I.: 1-21) in 2003. Three grey seals (95% C.I.: 0-10), and three harbour seals (95% C.I.: 0-9) were captured in 2002 (Table 5.4).

5.3.5 - The Offshore White Hake Fishery

No seals were reported as incidental catch in the gillnet fishery for white hake in the period 2001-2003.

5.3.6 - The Nearshore and Offshore Greenland Halibut Fishery

Five harp seals were reported by a single Bycatch Collector as incidental catch in the nearshore Greenland halibut fishery along the south coast in 2001. This equates to 58 harp seals captured in this area during 2001 (no 95% confidence limit available; Table 5.1, 5.3). No seals were reported caught by Bycatch Collectors in nearshore areas in 2002 or 2003.

Fishery Observers reported a single harp seal captured in the offshore Greenland halibut fishery in 2002. The event occurred in April 2002 near the southern Grand Banks (NAFO Division 3O), and indicates that approximately two harp seals (95% C.I.: 0-6) were captured in that area in 2002 (Tables 5.2, 5.4).

5.3.7 - The Nearshore and Offshore Redfish Fishery

No seals were reported as incidental catch in the gillnet fishery for redfish during 2001-2003.

5.3.8 - The Nearshore Winter Flounder Fishery

No seals were reported in 2001. In 2002, 4 seals were reported by Bycatch Collectors, of which 2 were harp seals, 1 was a ringed seal, and 1 an unidentified seal (presumed to be a harp seal). This equates to an estimated catch of 40 harp seals (95% C.I.: 0-86) and 11 ringed seals (95% C.I.: 0-34) in 2002 (Table 5.1, 5.3). All seals were captured along the northeast coast, and most were caught in the third quarter. In 2003, 2 harp seals were reported along the northeast coast by Bycatch Collectors. This represents an estimated incidental catch of 32 harp seals (95% C.I.: 0-79) in 2003 (Table 5.4). No seals were reproted by Fishery Observers.

5.4 - Discussion

The distribution of reports of incidental catches of seals generally reflects present knowledge about the distribution of these species. Hooded seals were only caught in the nearshore lumpfish fishery and in the cod fishery during the beginning of the season, reflecting their restricted seasonal presence in Newfoundland waters. Harp seals were reported in numerous different fisheries, but the vast majority of reports originated from the nearshore lumpfish fishery. However, several Fishery Observers reported harp seals caught in offshore fisheries along the southwestern Grand Banks during June and early July, indicating that some harp seals, at least, may seek out this area to forage while migrating out of the Gulf of St. Lawrence. This has also been reported by Stenson and Sjare (1997) using satellite telemetry. Harbour and grey seals were occasionally reported as incidental catch from both nearshore and offshore fisheries. No catches of ringed or bearded seals were reported by Fishery Observers, but Bycatch Collectors reported these species in lumpfish and winter flounder nets along the northeast and northwest coasts during spring and early summer, in areas where sea ice was seasonally present.

Stocks of harp, hooded, grey and harbour seals in Atlantic Canada have been targeted by a commercial hunt, as well as historically by organized culls, for decades or centuries (Bowering and Atkinson 2003; DFO 2003). Despite this often-substantial direct anthropogenic mortality, all of the stocks that have been studied appear to be either increasing or remaining stable (DFO 2000, 2003; Hammill and Stenson 2003; Hammill 2005; Sjare *et al.* 2005; Trzcinsky *et al.* 2005). Incidental catch of seals in gillnets does not appear to be a significant additional source of mortality based on present knowledge, although the status of harbour, ringed and bearded seals is largely unknown and requires further research. The incidental catch estimates reported here represent the first recent estimates for hooded, harbour, grey, bearded and ringed seals in Newfoundland and Labrador gillnet fisheries. Such data are important to determine trends in incidental catch that may prompt management decisions.

5.4.1 – Impact of Incidental Catch on Seal Stocks

Based on Bycatch Collector data, 51,786 seals of different species (overall 95% C.I. not available) were estimated to have been caught in various fisheries in Newfoundland waters during 2001-2003. Fishery Observers reported 2,695 seals during this period (95%C.I.: 250-5,883). The discrepancy between the two estimates is likely caused by the lack of Fishery Observer coverage in nearshore fisheries, particularly the lumpfish fishery.

The most commonly captured seal was the harp seal, and the majority of all seals were captured in the nearshore lumpfish fishery. This fishery has traditionally been known to catch large numbers of harp seals, due to its overlap with the spring harp seal migration (Walsh *et al.* 2000). Since harp seals typically travel in large herds, considerable numbers of seals can be captured at once, which may lead to high catch estimates (B. Sjare, DFO-NL, pers. comm.). The fishing season in most other fisheries typically starts in late May or early June, after most harp seals have left Newfoundland waters (G. Stenson, DFO-NL. pers. comm.). Offshore fisheries along the edge of the southwestern Grand Banks are thought to operate outside the main migratory corridor for the Gulf of St. Lawrence harp seal herd. However, some seals appear to spend time during summer foraging on the Grand Banks (Stenson and Sjare 1997). In addition, fishers involved in these fisheries typically set their nets in water depths of several hundred meters along the shelf edge. While harp seals have been shown to be capable of dives down to nearly 600 m, most dives appear to be in the upper 100 m of the water column, further reducing the chances of interactions with this fishing gear (Folkow *et al.* 2004). This may explain the limited catches of harp seals in the fishery for Greenland halibut along the shelf edge in NAFO Divisions 3KL (Fig. 1.3).

An earlier analysis of the Bycatch Collector dataset using landed catch (mt of lumpfish roe) as a measure of effort led to an annual estimated catch of 33,361 harp seals in this fishery (95% C.I.: 17,494-54,600; Sjare *et al.* 2005). A possible reason for the differences between these estimates may be the lower variability in numbers of net-days as a measure of fishing effort, when compared to landed catch (Chapter 3).

The current estimate of the harp seal population in Newfoundland waters is 5.9 million seals (95% C.I.: 4.6 million-7.2 million), with the population remaining relatively stable in recent years (DFO 2005). In Atlantic Canada, harp seals are managed according to a precautionary approach, which calls for the establishment of reference points for population size to identify potential conservation concerns. Specific management actions are triggered when the population reaches such reference points, placing greater emphasis on conservation as populations decrease (Hammill and Stenson 2003). As part of a five-year management plan, the quotas for the 2006 commercial harp seal hunt were set at 325,000 seals, which is in line with previous years (DFO 2003). The vast majority (~ 95%) of hunted harp seals are young of the year, known locally as "beaters" (DFO 2005). Incidental catch estimates of harp seals in the lumpfish fishery have been taken into account during the development of the existing management plan, but incidental catches in other fisheries have not been estimated until now (DFO 2005). Although the harp seal incidental catch estimates presented here are only 5-10% of the number of seals taken in the annual hunt, the fact that adult seals are also captured may have a greater impact on the population, and should be taken into account in the development of future management plans (DFO 2005).

Impacts of incidental catch estimates of other seal species in Newfoundland and Labrador waters are unknown due to a lack of current abundance data, but catch levels appeared to be relatively low. However, there is potential cause for concern about the incidental catch of harbour seals. Both

Bycatch Collector and Fishery Observer datasets indicate that several hundred harbour seals may have been captured during 2001-2003. Most of these seals were caught in lumpfish nets. Harbour seals are closely associated with specific haul-out sites during the annual molting and breeding seasons in spring and summer, and may therefore experience a high mortality in gillnets in adjacent areas (Lien *et al.* 1989; Ries *et al.* 1999; National Audubon Society 2002). However, the impact of that mortality on the population may not be evident due to a lack of information about harbour seal distribution, abundance, and seasonal movements (Sjare *et al.* 2005; J. Lawson, DFO-NL, pers. comm.). Harbour seals also migrate over shorter distances than harp seals, and so may be more affected by fishing activities (Bjørge *et al.* 1995; Thomson *et al.* 1996, 1998; Härkonen and Harding 2001; but see Lesage *et al.* 2004). Finally, harbour seals may be misidentified as juvenile harp seals, which may have negatively biased the harbour seal catch estimates. While the majority of harp seals leave Newfoundland waters during summer, small numbers remain in nearshore and offshore areas. It is therefore not always possible to assume that small spotted seals caught in Newfoundland waters outside the harp seal pupping and migrating season are harbour seals.

Based on historical data fitted to an abundance estimator model, harbour seal abundance was estimated at a 1996 populaton of 32,000 harbour seals in the entire Atlantic Canadian region (Hammill and Stenson 2000). Approximately

5,120 of these seals were considered to inhabit Newfoundland and Labrador waters. Based on this preliminary estimate and subsequent limited survey effort, several thousand harbour seals are thought to currently inhabit coastal Newfoundland and Labrador waters (Sjare *et al.* 2005). A value of 0.12 is often used as the theoretical maximum annual net productivity rate for seal populations (resulting from additions by reproduction, less losses through natural mortality; Barlow *et al.* 1995). The model developed by Hammill and Stenson (2000) used a 5.6% annual growth rate. For an estimated population of 5,000 harbour seals, this equates to an estimated annual pup production of 300-400. Incidental catch estimates calculated here imply an annual catch of 279 harbour seals (95% C.I.: 60-565) based on Fishery Observer data, or 247 harbour seals (95% C.I.: 0-680) based on Bycatch Collector data (Tables 5.1, 5.3). Although uncertainty of the present incidental catch estimates for harbour seals is considerable, it appears that incidental mortality in gillnets is approximately equal to pup production and hence may be a limiting factor for harbour seals in Newfoundland and Labrador waters. Harbour seals in Atlantic Canada and the northeastern United States are considered part of a single population, implying that migration from outside Newfoundland waters may maintain present levels of abundance (Anonymous 2005). However, studies in other areas indicate population structure at smaller geographic scales of hundreds of kilometers (Burg *et al.* 1999; Härkonen and Harding 2001; Westlake and O'Corry-Crowe 2002; Lesage *et al.* 2004). More information on harbour seal distribution and abundance is required for a better assessment of the current risks of incidental catch in gillnets to the provincial population of this species.

A similar problem exists for incidental catch of ringed and bearded seals along the northeast and west Newfoundland coasts. The confidence intervals associated with incidental catch estimates calculated here are wide. Nevertheless, several hundred ringed and bearded seals may be caught annually in nearshore lumpfish and winter flounder fisheries. The potential impact of this mortality is unknown, since no population estimates are available.

5.4.2 - Potential Methodological Problems and Suggestions for Improvement

During the course of these analyses, several problems were identified that decreased the accuracy of incidental seal catch estimates. Identification of seals may be a problem, as some were reported as "unidentified seal". Most of these were likely harp seals, but the possibility of incorrect identification cannot be excluded. Variable coverage of nearshore fisheries (such as the lumpfish fishery) by Fishery Observers may have led to lower incidental catch estimates. Finally, the Fishery Observers typically only recorded the total weight of incidentally caught seals, rather than the number of individuals. It was assumed that each capture event represented a single seal, except when reported weights indicated otherwise. In those cases, the likely minimum number of seals was used, based on maximum weights published in the literature. Having Fishery Observers record the estimated number of individuals involved would improve the quality of the data for monitoring incidental catch of seals. Equipping Observers with inexpensive digital cameras would also increase the likelihood of correct identifications.

5.5 - Conclusions

Incidental catches of several species of seals were estimated for various Newfoundland and Labrador gillnet fisheries, during 2001-2003. Catch rates of seal species ranged from several hundred to several thousand for this period. It is thought that harp seals' abundance and extensive spatial overlap with fishing gear led to high catch estimates relative to those for other species. Based on available data, the estimated incidental catch of harp seals in Newfoundland gillnet fisheries does not appear to be an immediate cause for concern. However, no current abundance estimates are available for most other seal species, and so the effect of incidental catch estimates reported here is unknown. Harbour seal catch levels appear high relative to this species' apparent population size in Newfoundland and Labrador, and may be cause for concern. Further information on seal distribution and abundance in Newfoundland waters would assist in assessing the risk of incidental mortality to these species.

5.6 - References

Anonymous. 2005. Harbour Seal (*Phoca vitulina*): Western North Atlantic Stock. National Marine Fisheries Service Marine Mammal Stock Assessment, Silver Springs, MD, USA; 6 pp. Available online at: http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2005sehr-wn.pdf

Barlow, J., S.L. Swartz, T.C. Eagle, and P.R. Wade. 1995. U.S. marine mammal stock assessments: Guidelines for preparation, background, and a summary of the 1995 assessments. U.S. Department of Commerce, NOAA Technical Memorandum NMFSOPR-6, 73 pp.

Berrow, S.D., M. O'Neill and D. Brogan. 1998. Discarding practices and marine mammal by-catch in the Celtic sea herring fishery. Biology and Environment: Proceedings of the Royal Irish Academy 98B (1): 1-8.

Bjørge, A., D. Thompson, P. Hammond, M. Fedak, E. Bryant, H. Aarefjord, R. Roen and M. Olsen. 1995. Habitat use and diving behaviour of harbour seals in a coastal archipelago in Norway. Page 211-223 In: Whales, seals, fish and man. IV. A. S. Blix, L. Walløe and Ø. Ultang (Ed.), Elsevier Science B.V., Tromsø, Norway.

Boulva, J, and I.A. McLaren. 1979. Biology of the harbor seal, (*Phoca vitulina*) in eastern Canada. Bulletin of the Fisheries Research Board of Canada 200: 25 pp.

Bowering, W.R. and D.B. Atkinson. 2003. Seal stocks in Canadian and NAFO waters. Management Strategies for Commercial Marine Species in Northern Ecosystems. Proceedings of the 10th Norwegian-Russian Symposium, Bergen, Norway, 27-29 August 2003. IMR/PINRO Joint Report Series no. 1: 148-151.

Burg, T.M., A.W. Trites and M.J. Smith. 1999. Mitochondrial and microsatellite DNA analyses of harbour seal population structure in the northeast Pacific Ocean. Canadian Journal of Zoology 77(6): 930-943.

Carretta, J.V., T. Price, D. Petersen and R. Read. 2004. Estimates of marine mammal, sea turtle, and seabird mortality in the California drift gillnet fishery for swordfish and thresher shark, 1996-2002. U S National Marine Fisheries Service Marine Fisheries Review 66 (2): 21-30.

Christensen, O. and W.H. Lear. 1977. Bycatches in salmon drift-nets at west Greenland in 1972. Kommissionen for Videnskabelige Undersøgelser i Grønland 205 (5): 5-37.

Cleator, H.J. 1996. The status of the bearded seal, *Erignathus barbatus*, in Canada. Canadian Field-Naturalist 110 (3): 501-510.

DFO [Department of Fisheries and Oceans]. 2000. Northwest Atlantic harp seals. Department of Fisheries and Oceans, Ottawa, ON, Canada: 7 pp.

DFO [Department of Fisheries and Oceans]. 2003. Atlantic Seal Hunt 2003-2005 Management Plan. Department of Fisheries and Oceans, Ottawa, ON,

Canada. Available at: http://www.dfo-mpo.gc.ca/seal-phoque/reports-rapports/mgtplan-plangest2003/mgtplan-plangest2003_e.htm#14.
DFO [Department of Fisheries and Oceans]. 2005. Stock assessment of Northwest Atlantic harp seals (*Pagophilus groenlandicus*). Canadian Science Advisory Secretariat (CSAS) Science Advisory Report 2005/037: 12 pp. Available online at: http://www.dfo-mpo.gc.ca/csas/Csas/status/-2005/SAR-AS2005_037_E.pdf.
Dyke, A.S., J. Hooper, C.R. Harrington and M. Savelle. 1999. The Late Wisconsinan and Holocene record of walrus (*Odobenus rosmarus*) from North America: A review with new data from Arctic and Atlantic Canada. Arctic 52 (2): 160-181.
Folkow, L.P., E.S. Nordøy and A.S. Blix (2004). Distribution and diving behaviour of harp seals (*Pagophilus groenlandicus*) from the Greenland Sea stock. Polar Biology 27: 281-298.
Gosselin, J.-F. and F. Boily. 1994. Unusual southern occurrence of a juvenile bearded seal, *Erignathus barbatus*, in the St. Lawrence Estuary, Canada. Marine Mammal Science 10 (4): 480-483.
Hammill, M.O. 2005. Abundance of Northwest Atlantic grey seals in the Gulf of St. Lawrence and along the Nova Scotia Eastern Shore. Canadian Science Advisory Secretariat Research Document 2005/036. DFO, Mont-Joli, QC, Canada: 15 pp. Available online at: www.dfo-mpo.gc.ca/csas.
Hammill, M.O. and G.B. Stenson. 2000. Estimated prey consumption by harp seals (*Phoca groenlandicus*), grey seals (*Halichoerus grypus*), harbour seals (*Phoca vitulina*) and hooded seals (*Cystophora cristata*). Journal of Northwest Atlantic Fisheries Science 26: 1-23.
Hammill, M.O. and G.B. Stenson. 2003. Application of the Precautionary Approach and Conservation Reference Points to the management of Atlantic seals: A discussion paper. Canadian Science Advisory Secretariat Research Document 2003/067. Department of Fisheries and Oceans, 23 pp. Available online at: www.dfo-mpo.gc.ca/csas
Hammill, M.O., G.B. Stenson, R.A. Myers, and W.T. Stobo. 1998. Pup production and population trends of the grey seal (*Halichoerus grypus*) in the Gulf of St. Lawrence. Canadian Journal of Fisheries and Aquatic Sciences 55: 423-430.
Harcourt, R., D. Aurioles and J. Sanchez. 1994. Entanglement of California sea lions at Los Islotes, Baja California Sur, Mexico. Marine Mammal Science 10 (1): 122-125.
Härkonen, T., and K.C. Harding. 2001. Spatial structure of harbour seal populations and the implications thereof. Canadian Journal of Zoology 79: 2115-2127.
Kakuschke, A., E. Valentine-Thon, S. Griesel, S. Fonfara, U. Siebert and A. Prange. 2005. Immunological impact of metals in harbor seals (*Phoca vitulina*) in the North Sea. Environmental Science & Technology 39: 7568-7575.

Kingsley, M.C.S. 1998. Walruses, *Odobenus rosmarus*, in the Gulf and Estuary of the St Lawrence, 1992-1996. Canadian Field-Naturalist 112 (1): 90-93.
Lavigne, D.M. and K. Kovacs. 1988. Harps and Hoods. University of Waterloo Press, Waterloo, ON, Canada.
Lesage, V., M.O. Hammill and K.M. Kovacs. 2004. Long-distance movements of harbour seals (*Phoca vitulina*) from a seasonally ice-covered area, the St. Lawrence River estuary, Canada. Canadian Journal of Zoology 82 (7): 1070-1081.
Lewison, R.L., L.B. Crowder, A.J. Read and S.A. Freeman. 2004. Understanding impacts of fisheries bycatch on marine megafauna. Trends in Ecology and Evolution 19 (11): 598-604.
Lien, J., J. Papineau and L. Dugan. 1987. Incidental entrapments of cetaceans, sharks and marine turtles in inshore fishing gear reported during 1987 in Newfoundland and Labrador. A preliminary report submitted to the Department of Fisheries and Oceans and the Newfoundland and Labrador Department of Fisheries. Memorial University of Newfoundland, St. John's, NL: 44 pp.
Lien, J., G.B. Stenson and I. Hsun-Ni. 1989. A review of incidental entrapment of seabirds, seals and whales in inshore fishing gear in Newfoundland and Labrador: a problem for fishermen and fishing gear designers. Proceedings of the 1988 World Symposium on Fishing Gear and Fishing Vessel Design, Newfoundland and Labrador Institute of Fisheries and Marine Technology, St. John's, NL, Canada: 67-71.
Manly, B.F.J., A. Seyb and D.J. Fletcher. 2002. Bycatch of fur seals (*Arctocephalus forsteri*) in New Zealand fisheries, 1990/91-1995/96, and observer coverage. Department of Conservation Science Internal Series #41, Wellington, New Zealand: 40 pp.
Morizur, Y., S.D. Berrow, N.J.C. Tregenza, A.S. Couperus and S. Pouvreau. 1999. Incidental catches of marine-mammals in pelagic trawl fisheries of the northeast Atlantic. Fisheries Research 41 (3): 297-307.
National Audubon Society. 2002. Guide to Marine Mammals of the World. Alfred A. Knopf, Inc., New York, NY, USA.
Pemberton, D., B. Merdsoy, R. Gales and D. Renouf. 1994. Interaction between offshore trawlers and harp and hooded seals off Newfoundland. Biological Conservation 68: 123-127.
Piatt, J.F. and D.N. Nettleship. 1987. Incidental catch of marine birds and mammals in fishing nets off Newfoundland, Canada. Marine Pollution Bulletin 18: 344-349.
Read, A.J., P. Drinker and S. Northridge. 2006. Bycatch of marine mammals in U.S. and global fisheries. Conservation Biology 20 (1): 163-169.
Reeves, R.R. 1998. Distribution, abundance and biology of ringed seals (*Phoca hispida*): an overview. Pages 9-45 in M. P. Heide-Jørgensen and C. Lydersen, eds. Ringed seals in the North Atlantic. NAMMCO Scientific Publications No.1, Tromsø, Norway.

Ries, E.H., I.M. Traut, A.G. Brinkman and P.J.H. Reijnders. 1999. Net dispersal of harbour seals within the Wadden Sea before and after the 1988 epizootic. Journal of Sea Research 41(3): 233-244.

Robillard, A., V. Lesage and M.O. Hammill. 2005. Distribution and abundance of harbour seals (*Phoca vitulina concolor*) and grey seals (*Halichoerus grypus*) in the Estuary and Gulf of St. Lawrence, 1994-2001. Canadian technical report of fisheries and aquatic sciences 2613: x + 152 pp.

Sergeant, D.E. 1991. Harp seals, man and ice. Canadian Special Publications on Fisheries and Aquatic Science 114: 153 pp.

Shaw, S.D., D. Brenner, A. Bourakovsky, C.A. Mahaffey and C.R. Perkins. 2005. Polychlorinated biphenyls and chlorinated pesticides in harbor seals (*Phoca vitulina concolor*) from the northwestern Atlantic coast. Marine Pollution Bulletin 50: 1069-1084.

Silvani, L., M. Gazo and A. Aguilar (1999). Spanish driftnet fishing and incidental catches in the western Mediterranean. Biological Conservation 90 (1): 79-85.

Sjare, B., M. Lebeuf and G. Veinott. 2005. Harbour seals in Newfoundland and Labrador: a preliminary summary of new data on aspects of biology, ecology and contaminant profiles. Canadian Science Advisory Secretariat Research Document 2005/030, 42. Available online at: www.dfo-mpo.gc.ca/csas/

Sjare, B., D. Walsh, G.B. Stenson and S. Benjamins. 2005. An update on harp seal (*Pagophilus groenlandicus*) bycatch estimates in the Newfoundland lumpfish fishery. Canadian Science Advisory Secretariat Research Document 2005/049: 23pp.

Stenson, G.B., M.O. Hammill, J.F. Gosselin and B. Sjare. 2000. 1999 pup production of harp seals, *Phoca groenlandica*, in the northwest Atlantic. Canadian Stock Assessment Secretariat Research Document 2000/080.

Stenson, G.B., and B.Sjare. 1997. Seasonal distribution of harp seals, *Phoca groenlandica*, in the northwest Atlantic. ICES C.M. 1997/CC:10 pp.

Thompson, P.M., B.J. McConnell, D.J. Tollit, A. McKay, C. Hunter, and P.A. Racey. 1996. Comparative distribution, movements and diet of harbour and grey seals from the Moray Firth, N.E. Scotland. Journal of Applied Ecology 33: 1572–1584.

Thompson, P.M., A. Mackay, D.J. Tollit, S. Enderby, and P.S. Hammond. 1998. The influence of body size and sex on the characteristics of harbour seal foraging trips. Canadian Journal of Zoology 76: 1044–1053.

Trzcinsky, M.K., R. Mohn and W.D. Bowen. 2005. Estimation of grey seal population size and trends at Sable Island. Canadian Science Advisory Secretariat Research Document 2005/067. Bedford Institute of Oceanography, Dartmouth, NS, Canada: 14 pp.

Tudela, S. 2004. Ecosystem effects of fishing in the Mediterranean: An analysis of the major threats of fishing gear and practices to biodiversity and marine habitats. FAO General Fisheries Commission for the Mediterranean Study #74, 58 pp.

Walsh, D., B. Sjare and G.B. Stenson. 2000. Preliminary Estimates of Harp Seal By-catch in the Newfoundland Lumpfish Fishery. Canadian Stock Assessment Secretariat Research Document 2000/078. 16 pp.

Waring, G.T., R.M. Pace, J.M. Quintal, C.P. Fairfield, K. Maze-Foley, N. Cabana, P.J. Clapham, T.V.N. Cole, G.L. Fulling, L.P. Garrison, A.A. Hohn, B.G. Maise, W.E. McFee, K.D. Mullin, D.L. Palka, P.E. Rosel, M.C. Rossman, F.W. Wenzel and A.L. Whitingham. 2003. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments - 2003. NOAA Technical Memorandum NMFSNE-182: 287 pp.

Westlake, R.L. and G.M. O'Corry-Crowe. 2002. Macrogeographic structure and patterns of genetic diversity in harbor seals (*Phoca vitulina*) from Alaska to Japan. Journal of Mammalogy 83 (4): 1111-1126.

Wickens, P. 1995. A review of operational interactions between pinnipeds and fisheries. FAO Fisheries Technical Paper 346; 86 pp.

Woodley, T.H. and D.M. Lavigne. 1991. Incidental capture of pinnipeds in commercial fishing gear. International Marine Mammal Association, Guelph, ON, Canada: 35 pp.

CHAPTER 6 - INCIDENTAL CATCH ESTIMATES OF SEABIRDS IN NEWFOUNDLAND AND LABRADOR GILLNET FISHERIES, 2001-2003

6.1 – Introduction

6.1.1 - An Overview of Seabird Incidental Catch in Fisheries

Entanglement in fishing gear is a significant source of incidental mortality for many species of seabirds worldwide (Tasker *et al.* 2000). The combined effects of numerous commercial fisheries operations pose a serious threat to seabirds, and have brought some species close to extinction (Brothers *et al.* 1999; FAO 1999; Tasker *et al.* 2000; Inchausti and Weimerskirch 2001). Globally, hundreds of thousands of seabirds are killed every year in pelagic and bottom-set longlines (Brothers *et al.* 1999; Inchausti and Weimerskirch 2001; Tuck *et al.* 2001, 2003; Nel *et al.* 2002; Gilman *et al.* 2005), pelagic driftnets (Carretta *et al.* 2004; Uhlmann *et al.* 2005) and pelagic and bottom-set gillnets (Piatt *et al.* 1984; Piatt and Nettleship 1987; Melvin *et al.* 1999; Österblom *et al.* 2002).

Seabirds are typically long-lived, mature relatively late in life, and produce small numbers of offspring during their reproductive cycle. Population growth rates are therefore often low, even under ideal circumstances. Large-scale mortality of birds can thus have a significant impact on the population, which may take many years to recover once depletion has taken place (Furness 2003). Incidental mortality in fisheries may be compounded by other anthropogenic impacts such as directed hunting, pollution and climate change, making incidental catch mitigation a potentially significant conservation concern (FAO 1999; Lewison *et al.* 2005; Montevecchi 2001).

The first step in addressing the problem of incidental catch of seabirds in fisheries is to identify the fisheries and seabird species involved, and to assess the potential magnitude of the fisheries-related mortality on the population, where possible (Cooper *et al.* 2000). Monitoring of seabird mortality in fisheries is complicated by their often wide-ranging habits, long migrations and inaccessibility of nesting sites. However, many species' distributions are thought to overlap with commercial fisheries to a significant degree. Some species, such as albatrosses, large petrels, and gulls, are attracted to fishing operations because of the opportunity to scavenge bait or fish offal near the surface, which may lead to inadvertent capture (McDermond & Morgan 1993; Montevecchi 2001). Other species such as alcids, cormorants, and shearwaters, get entangled in gillnets and driftnets as they pursue prey underwater and fail to detect the nets in time to prevent entanglement (Montevecchi 2001).

Consistent monitoring of incidental catch of seabirds can be difficult to achieve. Records of bird catches are rarely recorded in fishing log records. However, some fishery observer porammes do record bird catches, including the Fishery Observer Programme currently in place in Newfoundland and Labrador (Canada). At the same time, collecting information directly from commercial fishers may provide data in fisheries where observer effort is limited. In this study, incidental catch estimates of seabirds in Newfoundland and Labrador gillnet fisheries were calculated, based on data collected for Fisheries and Oceans Canada (DFO) by commercial fishers and Fishery Observers.

6.1.2 - Seabirds of Newfoundland and Labrador

The northwest Atlantic is a globally significant region for seabirds throughout the year (Burke *et al.* 2005). Groups of species that frequent these waters include two species of loons (common loon *Gavia immer* Brünnich and red-throated loon G. *stellata* Pontoppidan), northern fulmar (*Fulmarus glacialis* L.), five species of shearwaters (Cory's shearwater *Calonectris diomedea* Scopoli; greater shearwater *Puffinus gravis* O'Reilly; sooty shearwater *P. griseus* Gmelin; Manx shearwater *P. puffinus* Brünnich; Audubon's shearwater *P. lherminieri* Lesson), two species of storm-petrel (Leach's storm-petrel *Oceanodroma leucorhoa* Vieillot, and Wilson's storm-petrel *Oceanites oceanicus* Kuhl), northern gannet (*Morus bassanus* L.), two species of cormorants (great cormorant *Phalacrocorax carbo* L., and double-crested cormorant *P. auritus*

Lesson), various species of marine ducks (family Anatidae), numerous species of gulls, terns and jaegers (family Laridae), and six species of auks (family Alcidae; razorbill *Alca torda* L.; common murre *Uria aalge* Pontoppidan; thick-billed murre *U. lomvia* L.; dovekie *Alle alle* L.; black guillemot *Cepphus grylle* L.; and Atlantic puffin *Fratercula arctica* L.). A complete list of bird species occurring in Newfoundland inshore and offshore waters is provided by Mactavish *et al.* (2003). Several large seabird colonies exist within provincial boundaries, which are of global significance for Leach's storm petrels, Atlantic puffins and common murres, and of regional significance for gannets and northern fulmars (Brown *et al.* 1975; Montevecchi and Tuck 1987; Snow 1996). Many species aggregate in Newfoundland nearshore waters during and after the breeding season, while large numbers of other species (e.g. shearwaters) move into and through Atlantic Canadian waters during summer, fall and winter on annual migrations (Brown *et al.* 1975; Huetmann and Diamond 2000; Burke *et al.* 2005).

The problem of incidental mortality of seabirds in fishing gear in Newfoundland has long been recognized (Piatt *et al.* 1984; Piatt and Nettleship 1987; Chapdelaine 1997; Bakken and Falk 1998; Brothers *et al.* 1999; Chardine *et al.* 2000; Cooper *et al.* 2000; CWS 2001; Russell 2001; Troke 2002; Anonymous 2003; Wilhelm *et al.* 2003). However, there are few reliable recent estimates available. Many historical and current reports of incidental catch of seabirds, particularly alcids, involve the nearshore gillnet fishery for Atlantic cod

(*Gadus morhua*; Piatt *et al.* 1984; Piatt and Nettleship 1987; Chapdelaine 1997; CWS 2001; Russell 2001; Troke 2002; Wilhelm *et al.* 2003). This fishery was historically very important to rural Newfoundland and Labrador, but fishing effort was reduced considerably due to the widespread closure of commercial fisheries in 1992 and 1993, in response to declines in Atlantic cod stocks (Hutchings and Myers 1994; Sinclair and Murawski 1997). It is thought that these moratoria indirectly led to a decrease in seabird mortality through the removal of large numbers of gillnets associated with this fishery (Robertson *et al.* 2004). However, gillnets have remained in use in other fisheries, such as those targeting lumpfish (*Cyclopterus lumpus*), Greenland halibut (*Hippoglossoides platessoides*) and monkfish (*Lophius americanus*); in addition the nearshore cod fisheries have been intermittently reopened on a limited scale from 1997 onward (DFO 2006). There is a potential for many of these fisheries to negatively impact seabirds. Recent studies on incidental catch of seabirds in Newfoundland waters have focused largely on longline fisheries targeting various species including Atlantic cod and Greenland halibut (*Reinhardtius hippoglossoides*), rather than on gillnet fisheries (Brothers *et al.* 1999; Cooper *et al.* 2000; Kulka and Showell 2000; DFO-CWS National Working Group on Seabird Bycatch in Longline Fisheries 2003). This indicated the need for estimation of current seabird mortality in gillnet fisheries in Newfoundland and Labrador. During the course of research aimed at estimating incidental catches of small cetaceans in Newfoundland gillnet fisheries during the 2001-2003 seasons, additional reports became available of incidental catches of a wide variety of seabirds. These reports were used to calculate incidental catch estimates for these species. In the present chapter, the incidental catch of seabirds in various gillnet fisheries in Newfoundland and Labrador will be estimated, based on the methodology outlined in Chapters 3 and 4 An attempt will be made to assess the relative impact of different fisheries on seabird species, and to address regional variability in catches. Possible causes of differences among these incidental catch estimates will be discussed.

6.2 - Methods

6.2.1 – Description of Methods

Methodologies used to estimate incidental catch were described in detail in Chapters 3 and 4. Fisheries under review were identical to those described in Chapters 3 and 4. Incidental catch estimation analyses were performed at the geographic scale of coastlines, because it is unlikely that many non-breeding seabirds either restrict themselves to a single NAFO unit or are distributed uniformly around the island of Newfoundland. Only limited Fishery Observer data were available for NAFO area 4R.

An analysis at a smaller geographic scale was performed for several species of colonially nesting seabirds with limited foraging ranges (<100 km).

Species analyzed at this smaller geographic scale included gannets, common murres, Atlantic puffins and razorbills. Although these species are highly mobile and wide-ranging, their distribution is restricted during spring and summer, with adult birds foraging near breeding grounds (Cairns *et al.* 1987; Piatt and Nettleship 1987; Huettmann and Diamond 2000; Russell 2001; Davoren *et al.* 2003a, 2003b). Fisheries operating near breeding colonies were considered more likely to have a negative impact on these species than more distant fisheries. It was therefore decided to analyze the incidental catch dataset of these species at the smallest possible geographical scale, i.e., that of individual NAFO units. Such analyses prevented high rates of incidental catch in waters near breeding colonies from being used to artificially elevate the estimates of incidental catch in other coastal areas, where these birds might be less abundant. Where large bird colonies were located near the border between two NAFO units, fishing effort data from both adjacent units were used. This method may have underestimated incidental catch of these species, because incidental catch may have occurred at low levels in some areas without being detected by Bycatch Collectors or Fishery Observers. Confidence intervals could not be calculated for all cases due to data limitations.

As described in Chapter 4, Fishery Observers typically recorded the total weight of each incidentally caught species rather than total number of individuals. Any inaccuracy in terms of the number of individuals involved may significantly affect the final catch estimate. This study has attempted to minimize this bias by assuming the smallest possible number of individuals was involved in any given incident, by referencing total reported catch weights with average body weights reported in the literature. However, it is unknown how accurate the Fishery Observers were in recording the weights of the various seabirds encountered. In addition, Observers round small weights (< 1 kg) up to a single kilogram, but many seabirds weigh less than this. Having Observers record the number of captured individuals would enhance the utility of Fishery Observer data for monitoring incidental catch of seabirds.

6.2.2 - Identification of Seabirds

Correct identification of seabirds requires expertise and familiarity with the various species that might occur in an area, some of which might appear broadly similar to a layperson. This became apparent when analyzing the Bycatch Collector and Fishery Observer datasets. Fishers did not always appear to reliably differentiate several closely-related species of seabirds. This became particularly clear when studying alcids and shearwaters.

Bycatch Collectors did not appear to distinguish common murres from thick-billed murres, commonly referring to both species as 'turrs'. The former species breeds in several large colonies in the province, while the latter overwinters in Newfoundland waters before returning to arctic breeding grounds in spring. The relative proportions of common and thick-billed murres in incidental catch are therefore unknown, although it is assumed that most cases involved common murres, since most fishing effort occurred during the spring and summer. It is also not known how well fishers were able to separate other alcids from the common/thick-billed murre clade, particularly razorbills and - to a lesser extent - black guillemots.

A similar problem occurred in both the Bycatch Collector and Fishery Observer datasets, where captured shearwaters could not all be identified to species level. Five species of shearwaters are known to occur seasonally in Newfoundland waters, although greater and sooty shearwaters are by far the most abundant (see above). These may be very difficult to identify to species, particularly if the specimens have been dead and entangled in fishing gear for some time. Based on previous surveys in northwest Atlantic waters, it is thought that most specimens were greater and sooty shearwaters (Brown *et al.* 1975). Because of uncertainty in species identifications, the various species were combined when using Bycatch Collector data to provide a minimum estimate of incidental catch for this group (Brown *et al.* 1975; Mactavish *et al.* 2003). Species-specific estimates were calculated where possible when using Fishery Observer data, but some records were insufficiently detailed for this. Equipping Observers with inexpensive digital cameras and protocols for photographing dead specimens would increase the likelihood of correct identifications.

6.3 – *Results*

A detailed description of fishing effort in Newfoundland and Labrador can be found in Chapters 1 and 4, as well as Section 5.3.1.

6.3.1 - The Nearshore and Offshore Cod Fishery

Various species of seabirds were reported caught in the nearshore cod fishery by Bycatch Collectors (Table 6.1). The majority of incidental catch reports involved murres (*Uria* sp.), referred to as 'turrs' by most contributing fishers. Small sample sizes prevented the calculation of confidence intervals in several cases. However, confidence limits for those areas and periods where sufficient data were available were large, reflecting the high levels of uncertainty associated with these estimates.

In 2001, an estimated total of 7,708 murres were caught around the island, of which an estimated 5,559 (72% of total; no 95% C.I. available) were captured during the third quarter along the northeast coast near large breeding colonies such as Funk Island and Witless Bay on the Avalon Peninsula (NAFO units 3Ki, 3La and 3Lj; Fig. 1.4). An additional estimated 2,045 murres were captured near the Cape St. Mary's breeding colony on the south coast (NAFO units 3Lq and 3Psc; Fig. 1.4), 65 (95% C.I.: 0-195) during the second quarter and 1,980 (no

95% C.I. available) during the third quarter. Small numbers of murres (104, no 95% C.I. available) were also caught in the second quarter in the Strait of Belle Isle area along the west coast (NAFO unit 4Ra; Fig. 1.4). Data are summarised in Table 6.3.

In 2002, no murres were reported caught along the northeast coast, but an estimated 1,269 murres were caught near the Cape St. Mary's breeding colony on the south coast; 1,180 during the second quarter (no 95% C.I. available) and 88 (95% C.I.: 0-236) during the third quarter. An estimated 166 murres (95% C.I.: 0-498) were caught during the third quarter in the Strait of Belle Isle area, bringing the estimated annual total catch for 2002 to 1,435 murres.

Finally, in 2003, an estimated 1,468 murres were captured, all along the south coast near the Cape St. Mary's breeding colony (commercial fishery for cod was not permitted elsewhere this year). Of these, an estimated 279 murres (95% C.I.: 0-747) were caught during the second quarter, and the remaining 1,190 murres (95% C.I.: 0-2,998) were captured in the third quarter.

The only other species reported in the nearshore fishery by Bycatch Collectors were various species of shearwaters. Shearwaters were only reported in this fishery in 2001, during the third quarter (Table 6.2). An estimated 710 shearwaters (species unknown; 95% C.I.: 0-1,802) were caught along the south coast (Table 6.5).

In 2001, Fishery Observers also recorded numerous instances of murres captured in nearshore areas (Table 6.2). All reports originated in NAFO units 3Lj and 3Psc/3Lq off the east and south coast of the Avalon Peninsula, respectively, where large murre colonies are located. An estimated 9,888 murres (95% C.I.: 1,091-25,240) were caught in NAFO unit 3Lj during the third quarter. Along the south coast, in NAFO units 3PSc/3Lq, an estimated 2,349 murres (95% C.I.: 60-6,051) and 58 murres (95% C.I.:0-177) were caught in the third and fourth quarters, respectively. This equated to a total catch estimate of approximately 12,296 murres (95% C.I.: 1,151-31,468; Table 6.4). No murres were recorded by Fishery Observers in later years (Tables 6.2, 6.4).

Atlantic puffins were only recorded by Fishery Observers in the third quarter of 2001 (Table 6.2). An estimated 649 puffins (95% C.I.: 97-1,358) were caught in 2001 in NAFO unit 3Lj near the large puffin colony in the Witless Bay Islands Ecological Reserve (Table 6.4). No other Fishery Observer reports of incidental catches of puffins were available for this or other years.

Based on Fishery Observers data, an estimated 205 greater shearwaters (95% C.I.: 0-615) were caught along the south coast during the third quarter of

2001. During 2002, a further 120 greater shearwaters (95% C.I.: 0-360) were captured in nearshore waters along the south coast during the third quarter (Table 6.5). No shearwaters of any kind were reported caught in nearshore waters by Fishery Observers in 2003.

Fishery Observers also reported occasional captures of other bird species in this fishery including gannets (78; no 95% C.I. available) in the second quarter of 2001 and double-crested cormorants (136; 95% C.I.: 0-392) in the fourth quarter of 2001. Both of these species were only reported along the south coast (Table 6.2).

In the offshore gillnet fishery for cod in NAFO Subdivision 3Ps, Fishery Observers reported the capture of various seabird species, including murres and shearwaters (Table 6.2). Small numbers of murres were reported caught in offshore waters of NAFO Subdivision 3Ps during the fourth quarter of 2002 and 2003 (Table 6.2). An estimated 72 murres (95% C.I.: 0-197) were captured in 2002, and another four murres (no 95% C.I. available) in 2003 (Table 6.4). No murres were recorded in 2001.

No shearwaters were reported in 2001, but an estimated 909 and 3,139 greater shearwaters (95% C.I.: not available, and 653–6,382) were captured in the third and fourth quarter of 2002, respectively, leading to a total estimate of

4,049 greater shearwaters in 2002 (no overall 95% C.I. available). In contrast, only 119 greater shearwaters (no 95% C.I. available) were reported in 2003, all during the fourth quarter. Sooty shearwaters were only recorded during the third quarter of 2002 in small numbers (estimated catch of 89 birds; no 95% C.I. available), while small numbers of unidentified shearwaters were also recorded, solely in the fourth quarter of 2002 (estimated catch of 22 birds; 95% C.I.: 0-56; Table 6.5).

6.3.2 - The Nearshore Lumpfish Fishery

There were numerous reports from Bycatch Collectors of catches of seabirds in this fishery (Table 6.1). Most reports involved alcids, particularly murres. In 2001, an estimated 998 murres (no 95% C.I. available) were captured along the northeast coast, most in the vicinity of breeding colonies such as Funk Island (see above). An additional 279 murres (no 95% C.I. available) were caught near the Cape St. Mary's colony off the south coast, and an estimated 10 murres (no 95% C.I. available) were caught along the west coast, leading to a total catch estimate of 1,287 murres for 2001. In 2002, an estimated 1,954 murres (no 95% C.I. available) were captured in the vicinity of breeding colonies along the northeast coast. Along the south coast, no murres were reported caught, but an estimated 12 murres (no 95% C.I. available) were captured along the west coast. This generated a total catch estimate of 1,967 murres for 2002. In 2003, the only recorded catches of murres occurred along the northeast coast.

An estimated 608 murres (no 95% C.I. available) were caught in this area in this year.

Black guillemots were the next most commonly reported species; in 2001, an estimated 233 (95% C.I.: 47-471) were caught along the northeast coast, and an additional 19 (95% C.I.: 0-50) along the west coast, leading to an estimated total catch of 252 birds (95% C.I.: 47-521) in 2001. In 2002, an estimated 109 birds were caught (95% C.I.: 0-323); catches were only reported along the northeast coast. No black guillemots were reported caught anywhere in 2003.

Loons were reported captured in small numbers; in 2001, 39 loons (95% C.I.: 0-119) were caught along the northeast coast, while an additional 48 loons (95% C.I.: 1-108) were captured off the west coast, leading to a 2001 total estimate of 87 loons (95% C.I.: 1-226). In 2002, loons were only reported along the northeast coast; an estimated 27 loons (95% C.I.: 0-81) were caught this year. There were no records of loons captured anywhere in 2003.

There were occasional records of razorbills and double-crested cormorants in this fishery. An estimated 18 razorbills (95% C.I.: 0-41) were caught in 2001, and an estimated 7 razorbills (no 95% C.I. available) in 2002, in both years along the west coast. In 2001, a single cormorant (95% C.I.: 0-4) was estimated caught along the south coast. No other records of either razorbills or cormorants were available for other areas or years

In contrast, Fishery Observers did not report large numbers of birds being captured in this fishery (Table 6.2). The only species reported were common loon (along the northeast coast, only in 2001) and common eider (along the south coast, only in 2003). An estimated 384 loons (95% C.I.: 0-1,138) and 26 common eiders (95% C.I.: 0-77) were caught in this fishery in 2001 and 2003, respectively (Table 6.4). These species were not reported in other years.

6.3.3 - The Nearshore Herring Fishery

No seabirds were reported as incidental catch in the herring gillnet fishery during 2001-2003.

6.3.4 - The Offshore Monkfish and Skate Fishery

The only seabirds recorded as catch by Fishery Observers were greater and sooty shearwaters, as well as unidentified shearwaters (Table 6.2). An estimated 81 greater shearwaters (95% C.I.: 0-192) were caught in 2001. In 2002, an estimated 263 birds (95% C.I.: 33-605) were caught, while in 2003, an estimated 45 greater shearwaters (95% C.I.: 0-134) were captured. Sooty shearwaters were rarely recorded, with incidental catch estimates being consistently low (8 birds, 95% C.I.: 0-23 in 2001; 7 birds, 95% C.I.: 0-17 in 2002, and 6 birds, 95% C.I.: 0-19 in 2003). An estimated 47, 286 and 44 unidentified shearwaters (95% C.I.: 0-118; 17-770; and 0-156) were captured in 2001, 2002, and 2003, respectively (Table 6.5). When combining all species, an estimated total of 135 (95% C.I.:0-135), 556 (95% C.I.: 50-1,393) and 96 (95% C.I.: 0-309) shearwaters were caught in 2001, 2002 and 2003 (Table 6.5).

6.3.5 - The Offshore White Hake Fishery

Small numbers of shearwaters were reported by Fishery Observers in the offshore component of this fishery (Table 6.2). In 2001, an estimated 211 greater shearwaters were captured (no 95% C.I. available). In 2002, another estimated 7 birds (no 95% C.I. available) were caught (Table 6.5). No shearwaters were reported in 2003.

6.3.6 - The Nearshore and Offshore Greenland Halibut Fishery

Two murres were reported by a Bycatch Collector in the third quarter of 2001 in the nearshore Greenland halibut fishery in NAFO unit 3La (Table 6.1). This fishery took place in deep water (>350m), well beyond the normal diving range of murres. This incidental catch report is therefore considered to be anomalous, and has not been used to further estimate incidental catch in this fishery. Murres were not reported caught in other areas or years.

For the nearshore fishery, Fishery Observers reported occasional incidental catches of shearwaters and northern fulmar (Table 6.2). In the third quarter of 2001, an estimated 222 Cory's shearwaters (95% C.I.: 0-641), as well as an estimated 222 sooty shearwaters (95% C.I.: 0-641), were captured along the northeast coast. No records of shearwaters in nearshore waters are available for other years. An additional estimated 220 northern fulmars (95% C.I.: 0-641) were also caught in this area at this time (Table 6.5); this species was also not recorded here (or anywhere else in nearshore waters) in subsequent years.

Several other seabird species were reported by Fishery Observers in the offshore Greenland halibut fishery (Table 6.2). There were several records of northern fulmars from the offshore areas of NAFO Divisions 2GHJ3K during the third quarter of 2001. Based on these records, an estimated 75 fulmars (95% C.I.: 0-193) were captured in this region in 2001. A single gannet was reported captured by Fishery Observers in the third quarter of 2001 in the same area. This generated an estimated catch of 96 gannets (95% C.I.:0-249) in offshore waters of NAFO Divisions 2GHJ3K during 2001. A single dovekie was caught in the second quarter of 2003 in the offshore area of NAFO Divisions 3OPs, leading to an estimated catch of 22 dovekies in 2003 (no 95% C.I. available). None of these species were recorded elsewhere or in other years (Table 6.4).

Most seabirds reported caught in the offshore Greenland halibut fishery were shearwaters. In 2001, an estimated 66 greater shearwaters (no 95% C.I. available) were caught in NAFO Divisions 3OPs during the third quarter. Concurrently, an estimated 246 Cory's shearwaters (no 95% C.I. available) were captured in NAFO Divisions 3LN, while an estimated 37 sooty shearwaters (95% C.I.: 0-115) were caught in NAFO Divisions 2GHJ3K. This leads to a total estimated catch of 349 shearwaters of various species caught in 2001 (no 95% C.I. available). Two unidentified shearwaters (no 95% C.I. available) were caught in NAFO Divisions 3OPs during the second quarter of 2002, while an estimated 90 greater shearwaters (no 95% C.I. available) were captured in NAFO Divisions 2GHJ3K during the third quarter of 2002, leading to a total estimate of 92 shearwaters caught this year (no 95% C.I. available). No shearwaters were reported caught in 2003 (Table 6.5).

6.3.7 - The Nearshore and Offshore Redfish Fishery

No seabirds were reported as incidental catch in the gillnet fishery for redfish during 2001-2003, by either Bycatch Collectors or Fishery Observers.

6.3.8 - The Nearshore Winter Flounder Fishery

No seabirds were reported in 2001 by Bycatch Collectors. A single loon was reported captured along the northeast coast during the second quarter of 2002 (Table 6.1). This generated an estimated catch of 17 loons (95% C.I.: 0-52) along the northeast coast in this fishery in 2002 (Table 6.3). Three murres and one gannet were reported along the northeast coast near breeding colonies (NAFO units 3Ki, 3La and 3Lb; Fig. 1.4) by Bycatch Collectors during the second quarter of 2003. This represents an estimated incidental catch of 16 murres (95% C.I.: 0-44) and 8 gannets (95% C.I.: 0-24) in 2003 (Table 6.3). Fishery Observers reported a single sooty shearwater and at least one gannet in 2001, both along the south coast. Based on these records, this fishery may have caught an estimated 62 sooty shearwaters (no 95% C.I. available), and 171 gannets (no 95% C.I. available) in 2001. There were no reports of incidentally caught birds in 2002 or 2003 in this fishery.

6.4 - Discussion

6.4.1 - Potential Impacts of Gillnets on Seabirds in Newfoundland and Labrador Waters

Gillnet fisheries in Newfoundland and Labrador can capture considerable numbers of seabirds; however, not all species are at equal risk of entanglement in all fisheries. Diving depths vary greatly among different seabird species.

Northern fulmars are restricted to surface waters, rarely going deeper than 2 m (Hatch and Nettleship 1998; Garthe and Furness 2001). Species such as cormorants, eiders and loons typically forage in relatively shallow nearshore waters (<20 m), although loons are known to be capable of diving down to 60 m (Guillemette *et al.* 1993; McIntyre and Barr 1997; Hatch and Weselow 1999). Gannets typically plunge down from the air onto schools of prey fish and may occasionally reach depths of 22 m in this manner (Garthe *et al.* 2000). Shearwaters are known to pursue their prey underwater by swimming with both wings and feet, and several species have been recorded at depths of 60 m or more (Weimerskirch and Cherel 1998; Keitt *et al.* 2000; Burger 2001). Auks are particularly well adapted to diving, and some species such as the common murre and razorbill can reach depths of >100 m (Piatt and Nettleship 1985; Jury 1986; Ainley *et al.* 2002). However, these species typically dive no deeper than 50 m, while dovekie, puffin and black guillemot typically dive within the uppermost 20 m (Piatt and Nettleship 1985; Burger and Simpson 1986; Cairns 1992; Ainley *et al.* 2002; Lowther *et al.* 2002; B. Hooper, pers. comm., in Montevecchi and Stenhouse 2002). Clearly, birds that routinely dive deep in search of prey (such as shearwaters and auks) are at greater risk of encountering fishing gear. On the other hand, several species of seabirds occurring in Newfoundland and Labrador waters (e.g., gannets, northern fulmars, various species of shearwaters) are known to forage on discards around fishing vessels and may be more likely to get entangled in nets that are being set or hauled, particularly if such nets contain fish (Camphuysen *et al.* 1995; Camphuysen and Garthe 1997; Tasker *et al.* 2000).

Seabirds caught in gillnets may have encountered these nets deployed and fishing at depth while they themselves were pursuing prey underwater. Alternatively, the birds may have been captured by the nets as they were set or hauled; in the latter case, birds may have swum into the nets by accident, or attempted to forage on entangled fish or discards in the vicinity of the fishing vessel. Finally, birds that have died from other causes may be subsequently washed into nets.

It may be difficult to determine if an entangled bird was caught at depth or during setting/hauling operations. However, some captured birds in the present study were reported in gillnets fishing at depths far beyond the known diving range of the species in question (in the Greenland halibut and monkfish/skate fisheries, in particular).

Based on the data presented here, species such as eider ducks, double-crested cormorants, Cory's shearwaters, gannets, puffins, and dovekies were reported only rarely as incidental catch in gillnet fisheries in Newfoundland and Labrador between 2001 and 2003. Loons, black guillemots, razorbills, northern fulmars and Sooty shearwaters were reported more regularly, while the most commonly reported species were murres and Greater shearwaters, as well as unidentified shearwaters. These species also occurred in the widest range of fishing gears, reflecting their broad distribution.

Loons were only caught in nearshore fisheries along the northeast coast early in the fishing season, suggesting that the majority of cases involved wintering birds. Most murres and puffins were reported near breeding colonies, although murres were also reported by Fishery Observers in offshore cod catches in the fourth quarter of the year, when birds disperse offshore after the conclusion of the breeding season. Gannets displayed a similar pattern, although captures of these birds were reported less frequently. Catches of fulmars were only reported in the offshore Greenland halibut fishery in the Orphan Basin area and adjacent nearshore waters (NAFO Division 3KL and Units 3Ki/3Kh). Different species of shearwaters were reported in various nearshore and offshore fisheries that targeted cod, Greenland halibut, white hake, monkfish and skates, and winter flounder.

The groups of seabirds most commonly reported as caught throughout Newfoundland and Labrador waters were murres and shearwaters. Based on both Bycatch Collector and Fishery Observer data, several thousand murres (the majority of which are likely to have been common murres *U. aalge*) were caught annually during 2001-2003 in various nearshore gillnet fisheries. In contrast, Piatt and Nettleship (1987) reported an annual average of 22,070 common murres being caught near four major Newfoundland seabird colonies during the 1981-84 fishing seasons, 81% of which were caught in the cod gillnet fishery, which was widespread at the time. Clearly, the reduction in gillnet fishing effort since the cod moratoria has led to a reduction in incidental catch of common murres, although captures continue even at current low levels of gillnet fishing effort. Both Bycatch Collector and Fishery Observer data indicate that catches are highly variable from year to year, and are likely driven by occasional catches of large numbers of birds in episodic mortality events. Other alcids, such as black guillemots, razorbills and Atlantic puffins, are apparently captured less often in cod gillnets. The tendency of murres to form dense feeding aggregations might account for large numbers being captured at once (Piatt and Nettleship 1987; Robertson *et al.* 2004). Schools of capelin (*Mallotus villosus* Müller), the principal prey of murres, are patchily distributed, leading to a clustering of murres in areas of high capelin density (Davoren *et al.* 2003a). This could increase the likelihood of large numbers of murres being captured at once in small numbers of gillnets. Puffins also feed on these aggregations, but are smaller than murres and may therefore not get entangled to the same extent. Razorbills are uncommon compared to murres and puffins, and so are less likely to be reported as incidental catch. Black guillemots do not cluster in feeding aggregations and do not breed colonially in this region, limiting the potential for large numbers of this species to be caught at once (Brown *et al.* 1975).

It is unknown what caused the difference in incidental catch rates of murres in Bycatch Collector and Fishery Observer data in the nearshore lumpfish fishery, where Fishery Observers did not report any murres being caught, while this was the most commonly reported species in Bycatch Collector data. Possible causes include low Observer coverage, the possibility that Observers did not observe birds due to other responsibilities, or clustered distribution of murres (Davoren *et al.* 2003a).

The effects of this incidental mortality on the common murre population of Newfoundland and Labrador appear to be limited. The number of common murre pairs currently breeding in four major breeding colonies in Newfoundland (Funk Island, Baccalieu Island, Witless Bay and Cape St. Mary's) has been estimated at more than 500,000 pairs, of which over 400,000 nest on Funk Island, approximately 150,000 in Witless Bay, 4,000 and 10,000 on Baccalieu Island and Cape St. Mary's, respectively, and 2,600 on Cabot Island (Chardine 2000; Troke 2002; Davoren *et al.* 2003; CWS 2004; W. Montevecchi, MUN, pers. comm.). It is thought that mortality rates of murre colonies should not exceed 6-12 % of the population, in order to prevent declines (Piatt 1984). The total estimated annual incidental catch of common murres is not thought to exceed 5,000 (~ 1% of total provincial population) based on presently available data, although these data indicate that almost all of these birds were captured in the vicinity of breeding colonies. As an example, the incidental catch estimate of 12,296 murres (95% C.I.: 1,151-31,468; Table 6.4) during 2001 in the nearshore cod fishery in NAFO unit 3Lj off the east coast of the Avalon Peninsula represents approximately 4% (95% C.I.: 0.2-11%) of the breeding population of 150,000 pairs in the Witless Bay area. Such catch rates could affect the health of individual colonies, if fishing effort were to increase. In addition to the direct mortality through entanglement in gillnets, there is an effect on the breeding population through subsequent chick mortality. Murres do not breed until age 5-6, and produce a single chick each year (Ainley *et al.* 2002). Because foraging efforts from both parents are required for the successful rearing of a single chick, mortality of breeding murres in fishing gear is of concern (Ainley *et al.* 2002).

The vast majority of murre incidental catch appears to occur in nearshore Atlantic cod and lumpfish fisheries. The use of gillnets along the northeast coast of the island of Newfoundland has been limited since the closure of the large-scale commercial cod fisheries in 1992, and most nearshore gillnets are now deployed along the south coast of the island, where fewer murre colonies exist. The present data indicate that incidental mortality of common murres in gillnets continues, despite limited fishing effort, but at far smaller numbers than historically recorded. In 2006, a limited commercial fishery for cod was re-opened in nearshore waters along the northeast coast of the island of Newfoundland (DFO 2006). Although this fishery could cause some incidental catch of diving seabirds such as murres, levels of fishing effort are not considered to be high enough to lead to declines in seabird populations. Based on limited Fishery Observer data, the offshore gillnet fisheries do not appear to pose a significant risk to murres in Newfoundland and Labrador waters.

However, incidental catch of murres in gillnets represents but one source of mortality for this species in Newfoundland and Labrador. As indicated by beached bird surveys, oiled bird rates among Newfoundland murres are among the highest in the world, indicating the potential importance of oil pollution as a source of mortality among murres and other seabirds (Wiese and Ryan 2003). An estimated 300,000 alcids (common murres, thick-billed murres and dovekies) are estimated to die annually of oil pollution off southeastern Newfoundland (approximately 200,000 thick-billed murres, 31,000 common murres, and 69,000 dovekies; Wiese *et al.* 2004). During the winter months, common murres are also the target of a directed hunt in Newfoundland. The main target species is the migratory thick-billed murre, but common murres are also taken. Of the estimated 250,000 birds shot each year, as many as 5%, or 12,500 individuals, might be common murres (Chardine *et al.* 1999). Other types of impacts, such as disturbance of nesting sites, may also affect breeding success. Incidental catch in gillnets should therefore be considered as one of several potential sources of mortality for common murres, when reviewing management plans for this species.

The other potentially significant interaction between seabirds and gillnet fisheries occurs off the south coast of the island and involves species of shearwaters. If all estimates for incidental catch are combined, over 6,000 shearwaters may be captured on average each year in gillnet fisheries off Newfoundland's south coast. It is unknown why catch rates were so variable between years, since shearwaters are regular summer and fall visitors to the area (Huetmann and Diamond 2000). It is possible that the aggregating behaviour of greater shearwaters led to the interannual differences in catch rates (Brown et al. 1975).

Catches appear particularly high in the offshore cod fishery and lower in the fisheries for monkfish and skates, white hake and Greenland halibut. It is presently unknown how shearwaters get entangled in nets fishing for these latter species, as the nets are typically set at a depth of several hundred meters, which is considered to be below the diving range of these birds (Weimerskirch and Cherel 1998; Keitt *et al.* 2000; Burger 2001). Some shearwater species are known to scavenge near fishing vessels and it is possible that these species get entangled in these nets as they are being set or hauled. This appears likely if the hauling process takes a considerable amount of time, during which nets with fish are suspended close to the surface near the fishing vessel (Brown *et al.* 1975;

Piatt 1984; W. Montevecchi, MUN, pers. comm.). Further research is needed to assess this.

An estimated two to three million shearwaters of various species occur seasonally in Newfoundland waters, of which the majority are greater shearwaters (Brown *et al.* 1975; Montevecchi 2000). Many of these birds forage on the southern Grand Banks in late summer, where they overlap with fisheries for monkfish and skates, white hake, and cod. It is unlikely that the incidental catches of shearwaters reported here are high enough to be an immediate cause for concern. Shearwaters are both long-lived and highly migratory, with pairs producing a single chick each year. During their annual migrations, it is likely they will experience mortality in numerous fisheries such as the gillnet fisheries in Newfoundland and Labrador, the cumulative impact of which may be significant in the long term. There is a need for a detailed analysis of incidental catch of these species in fisheries throughout the North Atlantic, similar to the one performed by Uhlmann *et al* (2005) for incidental catch of sooty and short-tailed shearwaters (*Puffinus tenuirostris* Temminck) in driftnet fisheries throughout the Pacific.

6.4.2 - Potential Methodological Problems and Suggestions for Improvement

The ability to correctly identify seabirds is essential for accurate incidental catch estimation. Both Bycatch Collectors and Fishery Observers appear to have difficulty identifying certain groups of seabirds, particularly auks and shearwaters. Fishery Observers are most likely to receive additional training (Chapter 4), assuming their data are reviewed for potential identification errors. Bycatch Collectors require additional training, but not all Collectors may have an interest in becoming proficient in seabird identification. Given the abundance of greater shearwaters in Newfoundland waters, the task of identification could be simplified to determining whether or not captured specimens are *P. gravis*. If a specimen is not a *P. gravis*, photographs might allow for more detailed subsequent identification. Similarly, whole birds or wings could be stored frozen for later identifcation, if conditions aboard the vessel permit such sample collection.

Problems with Fishery Observer coverage are similar to those described in Chapter 4. Coverage is limited or absent in several nearshore fisheries, largely due to lack of financial means to afford extension of the Observer programme. Accurately recording these relatively rare episodic mortality events requires a high level of observer coverage that can only be achieved through considerable investment in manpower (Babcock *et al.* 2003). Bycatch Collector data may be used to describe incidental catch in these fisheries, but that database also suffers from lack of coverage in some fisheries that may capture seabirds (e.g. nearshore gillnet fishery for Atlantic herring). An expansion of the Bycatch Collector programme to include more fishers active in these fisheries is desirable.

6.5 - Conclusions

Despite reductions in landings, current gillnet fisheries in Newfoundland and Labrador waters continue to catch various species of seabirds. Based on data for gillnet fisheries during the 2001, 2002 and 2003 fishing seasons, an estimated several thousand murres, several thousand shearwaters of various species, several hundred loons, gannets, Atlantic puffins and black guillemots, and smaller numbers of other alcids, cormorants, fulmars, and eider ducks were captured in gillnets each year. Several sources of bias have likely negatively influenced these estimates, such as a lack of information about actual numbers of incidentally caught birds, identification problems, and low observer coverage. Despite these difficulties, the fisheries for cod, lumpfish, monkfish and skates, white hake and Greenland halibut appear to be responsible for the majority of incidental catch of seabirds in gillnets in Newfoundland and Labrador, while herring, redfish and winter flounder fisheries appear less important. Although catches are directly linked to fishing effort, they remain a relatively rare occurrence, so it is difficult to determine where incidental catch is likely to occur.

However, nearshore fisheries operating near seabird colonies are likely to experience high incidental catch rates. Likewise, high catch rates may occur in areas of high productivity, such as the southern Grand Banks.

Catch estimates of murres and shearwaters in Newfoundland waters are considered a potential concern. Populations of these species are not presently thought to be declining as a result of this incidental mortality; however, populations might be affected if fishing effort were to increase following fish stock recovery. Shearwaters' extensive migrations ensure interactions with numerous fisheries throughout the north Atlantic, the cumulative effect of which may be significant. More information is required on the degree of overlap of these species with fisheries. It is suggested that incidental catch estimates be incorporated in management plans for these species, and that mitigation efforts be undertaken wherever necessary.

6.6 - References

Ainley, D.G., D.N. Nettleship, H.R. Carter, and A.E. Storey. 2002. Common Murre (*Uria aalge*). *In* A. Poole and F. Gill (eds.): The Birds of North America, No. 666. The Birds of North America, Inc., Philadelphia, PA., USA.

Anonymous. 2003. DFO-CWS National Working Group on Seabird Bycatch in Longline Fisheries. Status Report and future directions towards the development of a National Plan of Action for the reduction of incidental catch of seabirds in domestic and foreign longline fisheries in Canadian waters. Canadian Technical Report of Fisheries and Aquatic Sciences 2471. Department of Fisheries and Oceans and Canadian Wildlife Service, Ottawa, ON, Canada: 50 pp.

Bakken, V. and K. Falk (eds). 1998. Incidental take of seabirds in commercial fisheries in the arctic countries. CAFF Technical Report No. 1: 50 pp.

Brothers, N.P., J. Cooper and S. Løkkeborg. 1999. The incidental catch of seabirds by longline fisheries: worldwide review and technical guidelines for mitigation. FAO Fisheries Circular, Rome, Italy: 100. Available online at: http://www.fao.org/documents/-show_cdr.asp?url_file=/DOCREP/005/W9817E/W9817E00.HTM

Burger, A. E., and M. Simpson. 1986. Diving depths of Atlantic Puffins and Common Murres. Auk 103: 828–830.

Burger, A.E. 2001. Diving depths of shearwaters. Auk 118 (3): 755-759.

Burke, C.M., G.K. Davoren, W.A. Montevecchi and F.K. Wiese. 2005. Surveys of seabirds along support vessel transects and at oil platforms on the Grand Banks. Pages 587-614 in: P.J. Cransford and K. Lee (Eds.): Offshore Oil and Gas Environmental Effects Monitoring. Battele Press, Columbus, Ohio

Cairns, D.K. 1992. Diving behavior of Black Guillemots in northeastern Hudson Bay. Colonial Waterbirds 15: 245–248.

Cairns, D.K., K.A.Bredin, and W.A.Montevecchi. 1987. Activity budgets and foraging ranges of breeding common murres. Auk 104: 218-224.

Camphuysen, C.J., B. Calvo, J. Durinck, K. Ensor, A. Follestad, R.W. Furness, S. Garthe, G. Leaper, H. Skov, M.L. Tasker, and C.J.N. Winter. 1995. Consumption of discards by seabirds in the North Sea. Final Report of EC DG XIV Research Contract BIOECO/93/10. NIOZ-Report 1995–5. Netherlands Institute for Sea Research, Texel. 202 pp.

Camphuysen, C.J., and S. Garthe. 1997. An evaluation of the distribution and scavenging habits of northern fulmars (*Fulmarus glacialis*) in the North Sea. ICES Journal of Marine Science 54: 654-683.

Carretta, J.V., T. Price, D. Petersen and R. Read. 2004. Estimates of marine mammal, sea turtle, and seabird mortality in the California drift gillnet fishery for swordfish and thresher shark, 1996-2002. U S National Marine Fisheries Service Marine Fisheries Review 66 (2): 21-30.

Chapdelaine, G. 1997. Pattern of recoveries of banded razorbills (*Alca torda*) in the western Atlantic and survival rates of adults and immatures. Colonial Waterbirds 20 (1): 47-54.

Chardine, J.W., B.T. Collins, R.D. Elliot, H. Levesque and P.C. Ryan. 1999. Trends in the annual harvest of murres in Newfoundland and Labrador. Bird Trends 7: 11-14.

Chardine, J.W., J.M.Porter and K.D.Wohl (eds.). 2000. Workshop on seabird incidental catch in the waters of Arctic countries. Report and recommendations. CAFF Technical Report No. 7: 71 pp.

Cooper, J., E. Dunn, D.W. Kulka, K. Morgan and K.S. Rivera. 2000. Addressing the problem: seabird mortality from longline fisheries in the waters of Arctic countries. Page 33-42 in K. D. Wohl (ed.): Workshop on seabird incidental catch in the waters of Arctic Countries. CAFF Technical Report No. 7, Dartmouth, NS, Canada.

CWS [Canadian Wildlife Service]. 2004. Population Status of Migratory Game Birds in Canada (and Regulation Proposals for Overabundant Species) - November 2004. Canadian Wildlife Service Report. Available online at: http://www.cws-scf.ec.gc.ca/publications/status/nov04/cont_e.cfm.

Davoren, G.K., W.A. Montevecchi and J.T. Anderson. 2003a. Distributional patterns of a marine bird and its prey: habitat selection based on prey and conspecific behaviour. Marine Ecology Progress Series 256: 229-242.

Davoren, G.K., W.A. Montevecchi and J.T. Anderson. 2003b. Search strategies of a pursuit-diving marine bird and the persistence of prey patches. Ecological Monographs 73 (3): 463-481.

Davoren, G.K., W.A. Montevecchi and J.T. Anderson. 2003c. The influence of fish behaviour on search strategies of common murres *Uria aalge* in the northwest Atlantic. Marine Ornithology 31: 123-131.

DFO [Department of Fisheries and Oceans]. 2006. New Government Programme to test the health of Cod Stocks. Department of Fisheries and Oceans News Release, 1 pp. Available online at: http://www.dfo-mpo.gc.ca/media/newsrel/2006/hq-ac14_e.htm.

FAO [Food and Agriculture Organization of the United Nations]. 1999. International Plan of Action for reducing incidental catch of seabirds in longline fisheries. Food and Agriculture Organisation (FAO), Rome, Italy: 10. Available online at: www.fao.org.

Furness, R.W. 2003. Impacts of fisheries on seabird communities. Scientia Marina 67 Supplement 2): 33-45.

Garthe,S., S. Benvenuti, and W. A. Montevecchi. 2000. Pursuit plunging by Northern Gannets (*Sula bassana*) feeding on capelin (*Mallotus villosus*). Proceedings of the Royal Society of London 267: 1717–1722.

Garthe, S., and R. W. Furness. 2001. Frequent shallow diving by a northern fulmar feeding at Shetland. Waterbirds 24(2): 287-289.

Gilman, E., N. Brothers and D.R. Kobayashi. 2005. Principles and approaches to abate seabird by-catch in longline fisheries. Fish and Fisheries 6: 35-49.

Guillemette, M., J. H. Himmelman, and C. Barette. 1993. Habitat selection by Common Eiders in winter and its interaction with flock size. Canadian Journal of Zoology 71: 1259–1266.

Hatch, S.A., and D.N. Nettleship. 1998. Northern Fulmar (*Fulmarus glacialis*). In The Birds of North America, No. 361 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Hatch, J.J., and D.V. Weseloh. 1999. Double-crested Cormorant (*Phalacrocorax auritus*). In The Birds of North America, No. 441 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Huettmann, F. and A.W. Diamond. 2000. Seabird migration in the Canadian northwest Atlantic ocean: moulting locations and movement patterns of immature birds. Canadian Journal of Zoology 78 (4): 624-647.

Hutchings, J.A. and R.A. Myers. 1994. What can be learned from the collapse of a renewable resource? Atlantic cod, *Gadus morhua*, of Newfoundland and Labrador. Canadian Journal of Fisheries and Aquatic Sciences 51: 2126 - 2146.

Inchausti, P. and H. Weimerskirch. 2001. Risks of decline and extinction of the endangered Amsterdam albatross and the projected impact of long-line fisheries. Biological Conservation 100: 377-386.

Jury, J.A. 1986. Razorbill swimming at depth of 140 m. British Birds 79: 339.

Keitt, B.S., D.A. Croll and B.R. Tershy. 2000. Dive depth and diet of the black-vented shearwater (*Puffinus ophistomelas*). Auk 117 (2): 507-510.

Kulka, D.W. and M. Showell. 2000. Seabird bycatch on longline fisheries in Atlantic Canada. Page 19 in K. D. Wohl (ed.): Workshop on seabird incidental catch in the waters of Arctic countries. CAFF Technical Report No. 7.

Lewison, R.L., D.C. Nel, F. Taylor, J.P. Croxall and K.S. Rivera. 2005. Thinking big - taking a large-scale approach to seabird bycatch. Marine Ornithology 33 (1): 1-5

Lowther, P. E., A. W. Diamond, S. W. Kress, G. J. Robertson, and K. Russell. 2002. Atlantic Puffin (*Fratercula arctica*). In The Birds of North America, No. 709 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Mactavish, B., J.E. Maunder, W.A. Montevecchi, J.L. Wells and D.A. Fifield. 2003. Checklist of the birds of insular Newfoundland and its continental shelf waters. The Natural History Society of Newfoundland and Labrador. Available online at: http://www.nhs.nf.ca/cbc_etc/checklist.htm

McIntyre, J.W., and J.F. Barr. 1997. Common Loon (*Gavia immer*). In The Birds of North America, No. 313 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Melvin, E.F., J.K. Parrish and L.L. Conquest. 1999. Novel tools to reduce seabird bycatch in coastal gillnet fisheries. Conservation Biology 13(6): 1386-1397.

Montevecchi, W.A. 2000. Seabirds. Pages 15-18 in: A. Bundy, G.R. Lilly and P.A. Shelton (eds.): A Mass Balance Model of the Newfoundland-Labrador Shelf. Canadian Technical Report of Fisheries and Aquatic Sciences 2310: 172 pp.

Montevecchi, W.A. 2001. Interactions between fisheries and seabirds. Pages 527-557 in J. Burger (ed.): The Biology of Marine Birds. CRC Press, Boca Raton, FL, USA.

Montevecchi, W. A., and I. J. Stenhouse. 2002. Dovekie (*Alle alle*). In The Birds of North America, No. 701 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Montevecchi, W.A. and L.M. Tuck. 1987. Newfoundland birds: exploitation, study, conservation. Publications of the Nuttall Ornithological Club 21. 273 pp.

Nel, D.C., P.G. Ryan, J.L. Nel, N.T.W. Klages, R.P. Wilson, G. Robertson and G.N. Tuck. 2002. Foraging interactions between Wandering Albatrosses *Diomedea exulans* breeding on Marion Island and long-line fisheries in the southern Indian Ocean. Ibis 144: E141-E154.

Österblom, H., T. Fransson and O. Olsson. 2002. Bycatches of common Guillemot (*Uria aalge*) in the Baltic Sea gillnet fishery. Biological Conservation 105: 309-319.

Piatt, J. 1984. Net mortality of marine birds in Newfoundland, 1981-82. Report No. 136, Seabird Research Unit, Canadian Wildlife Service, Bedford Instiotute of Oceanography, Dartmouth, NS, Canada; 90 pp.

Piatt, J.F., and D.N. Nettleship. 1985. Diving depths of four alcids. Auk 102: 293–297.

Piatt, J.F., and D.N. Nettleship. 1987. Incidental catch of marine birds and mammals in fishing nets off Newfoundland, Canada. Marine Pollution Bulletin 18: 344-349.

Piatt, J. F., D.N. Nettleship, and W. Threlfall. 1984. Net-mortality of Common Murres and Atlantic Puffins in Newfoundland, 1951-81. Pages 196-206 *in* D. N. Nettleship, G. A. Sanger, and P. F. Springer (eds). Marine birds: their feeding ecology and commercial fisheries relationships. Supply and Services Canada, Ottawa.

Russell, J. 2001. Marine bird important bird areas in southeastern Newfoundland: Conservation concerns and potential strategies. Report prepared for the Canadian Nature Federation and the Natural History Society of Newfoundland and Labrador, 125 pp.

Sinclair, A.F. and S.A. Murawski. 1997. Why have groundfish stocks declined? Pages 71-94 in J. Boreman, B.S. Nakashima, J.A.Wilson, and R.L. Kendall (eds.): Northwest Atlantic Groundfish: Perspectives on a Fishery Collapse. American Fisheries Society, Bethesda, MD, USA.

Snow, D. A. 1996. A Self-driving guide: Seabirds. Department of Tourism, Culture and Recreation, Government of Newfoundland and Labrador, Canada.

Tasker, M.L., C.J. Camphuysen, J. Cooper, S. Garthe, W.A. Montevecchi and S.J.M. Blaber. 2000. The impacts of fishing on marine birds. ICES Journal of Marine Science 57 (3): 531-547.

Troke, G. 2004. Estimating bycatch of common murres (*Uria aalge*) in gill-nets adjacent to breeding colonies in Newfoundland. M.Sc. thesis, Memorial University of Newfoundland, St. John's, NL, Canada; 16 pp.

Tuck, G.N., T. Polachek and C.M. Bulman. 2003. Spatio-temporal trends of longline fishing effort in the Southern Ocean and implications for seabird bycatch. Biological Conservation 114: 1-27.

Tuck, G.N., T. Polachek, J.P. Croxall and H. Weimerskirch. 2001. Modelling the impact of fishery by-catches on albatross populations. Journal of Applied Ecology 38: 1182-1196.

Uhlmann, S., D. Fletcher and H. Moller. 2005. Estimating incidental takes of shearwaters in driftnet fisheries: lessons for the conservation of seabirds. Biological Conservation 123: 151-163.

Weimerskirch, H., and Y. Cherel. 1998. Feeding ecology of short-tailed shearwaters: Breeding in Tasmania and foraging in the Antarctic?. Marine Ecology Progress Series 167: 261-274.

Wiese, F.K., and G.J. Robertson. 2004. Assessing seabird mortality from chronic oil discharges at sea. Journal of Wildlife Management 68(3): 627-638.

Wiese, F.K., and P.C. Ryan. 2003. The extent of chronic marine oil pollution in southeastern Newfoundland waters assessed through beached bird surveys 1984-1999. Marine Pollution Bulletin 46(9): 1090-1101.

Wilhelm, S.I., G.J. Robertson, P.A. Taylor, S.G. Gilligand and D.L. Pinsent. 2003. Stomach contents of breeding common murres caught in gillnets off Newfoundland. Waterbirds 26 (3): 376-378.

CHAPTER 7 - INCIDENTAL CATCH ESTIMATES OF SHARKS AND ASSORTED BONY FISH IN NEWFOUNDLAND AND LABRADOR GILLNET FISHERIES, 2001-2003

7.1 - Introduction

7.1.1 - An Overview of Incidental Catch of Elasmobranchs in Fisheries

High levels of incidental catch of elasmobranchs (sharks, rays, and chimaeras) in fisheries have become a conservation concern in recent years (FAO 1998; IUCN 2006). Stocks of many species are reported to be declining, and several (e.g. barndoor skate [*Raja batis*], sawfishes [Pristidae], deepwater sharks) are considered globally threatened or endangered (Thorson 1982;Casey and Myers 1998; Simpfendorfer 2000; Stevens *et al.* 2000; Kiraly *et al.* 2003; IUCN 2006). Sharks and rays are caught in a wide variety of fishing gears including gillnets, longlines and trawls (Bonfil 1994; Stevens *et al.* 2000; Carbonell *et al.* 2003; Carretta *et al.* 2004; Diaz and Serafy 2005; Shepherd and Myers 2005). Worldwide, reported elasmobranch landings have been stable at approximately 800 metric tons since 1996 (FAO 2004). However, actual catches are thought to be almost twice as high, due to substantial incidental and unreported catches (Bonfil 1994). Smaller, more rapidly maturing shark species may increase if populations of larger, slow-growing sharks are reduced (Shepherd and Myers 2005). Also, deepwater species are now caught with increasing frequency due to expansion of deepwater fisheries, such as seamount fisheries for orange roughy (Kiraly *et al.* 2003). In many fisheries statistics, elasmobranch catches are not identified to species, further complicating attempts to assess the potential impact of fisheries (Stevens *et al.* 2000).

Sharks and rays are considered vulnerable to overexploitation due to specific life-history traits. Most species grow slowly, mature late, have low reproductive rates, and are long-lived, factors that make them vulnerable to widespread juvenile or adult mortality (Castro *et al.* 1999; Stevens *et al.* 2000; Lewison *et al.* 2004). Some directed fisheries for sharks have been managed for many years at a sustainable level, but most catches of elasmobranchs occur in fisheries targeting an assemblage of different teleost species (Walker 1998). Management strategies intended to maximize the catches of these teleosts tend to deplete stocks of sharks and rays, because teleost populations are typically able to withstand higher levels of fishing mortality. Furthermore, many species are distributed over large areas in international waters, and population estimates are often incomplete or nonexistent. These factors complicate attempts to establish a conservation strategy for many species of elasmobranchs.

During the course of research aimed at estimating incidental catches of small cetaceans in Newfoundland gillnet fisheries during 2001-2003, additional reports became available of incidental catches of a wide variety of sharks and large bony fish. These were used to calculate incidental catch estimates. Here, the incidental catches of sharks in various gillnet fisheries in Newfoundland and Labrador are estimated, using a methodology developed for the assessment of small cetaceans described in detail in Chapters 3 and 4. These incidental catch estimates are compared to abundance estimates, where available, and the fisheries most likely to capture different species are identified. Various species of bony fish were also encountered as incidental catch in these fisheries, and their catch estimates are included in this chapter. There were no available data on incidental catches of different species of skates or chimaeras during 2001-2003, and therefore these species are not included in the present analysis.

7.1.2 - Sharks of Newfoundland and Labrador

Several species of sharks occur regularly in Newfoundland and Labrador waters. These include large, pelagic species such as the blue shark (*Prionace glauca* L.), porbeagle (*Lamna nasus* Bonnaterre) and shortfin mako (*Isurus oxyrinchus* Rafinesque); the large, filter-feeding basking shark (*Cetorhinus maximus* Gunnerus); small schooling sharks of the continental shelf such as the spiny dogfish (*Squalus acanthias* L.); and sharks from deeper, colder waters such as the Greenland shark (*Somniosus microcephalus* Bloch and Schneider) and the black dogfish (*Centroscyllium fabricii* Reinhardt). Numerous other species have been reported as incidental catch in small numbers over the years (Hurley 1998).

For the majority of these species, little is known about their abundance, movements and habitat requirements in the northwest Atlantic. The larger pelagic sharks (blue, porbeagle, shortfin mako) are typically associated with warmer waters off the south Newfoundland coast, although porbeagle sharks are more tolerant of colder waters than other species (Scott and Scott 1988). They are most abundant during summer and fall, when warmer waters are present near shore. Porbeagles are thought to mate on the southern Grand Banks and near Cabot Strait during early summer (Campana *et al.* 2003; Fig. 1.2).

Basking sharks forage along oceanic fronts where zooplankton concentrations are highest, and their occurrence in nearshore waters is therefore dependent on these conditions (Sims *et al.* 1997; Sims and Quayle 1998). They are most commonly reported from the south coast. Sightings of this species in nearshore waters of Newfoundland have become rare in recent years, but the reasons for this apparent decline are unknown.

Schools of spiny dogfish seasonally appear nearshore during summer, particularly along the south coast. These schools migrate along the continental shelf, and can consist of hundreds or thousands of dogfish, typically segregated by sex. Migrations of these schools are likely influenced by water temperature (Castro *et al.* 1999).

Other small sharks that are occasionally found in shallow water include the black dogfish, although this species and several others such as the Portuguese shark (*Centroscymnus coelolepis* Barbosa du Bocage and Brito Capello) and deepsea catshark (*Apristurus profundorum* Goode and Bean) are far more common in deeper, colder waters along the continental slope. They share this habitat with the Greenland shark, which is only rarely reported from shallow nearshore waters. All of these cold-water species are found closer to the surface at higher latitudes, particularly in the Arctic (NAFO Division 0A/B).

7.1.3 - Sharks and Fisheries in Newfoundland and Labrador

Directed fisheries for sharks have been limited in Newfoundland and Labrador, but from the 1960s onward, some trawling effort has been directed toward spiny dogfish, while large pelagic sharks such as porbeagle, blue and shortfin mako have been caught on longlines (Templeman 1966). In the 1990s, catches of pelagic sharks (porbeagle, blue, shortfin mako) in Atlantic Canada increased substantially with the development of a directed longline fishery, reaching their peak of 1,922 mt for all three species combined in 1994. Most catches took place along the Scotian shelf, but some occurred on the Grand

Banks (Hurley 1998). At the moment, porbeagle and blue sharks are targets of a directed fishery, with shortfin mako retained as incidental catch (DFO 2002). Populations appear to have declined due to overexploitation in recent years (Campana *et al.* 2003, 2004, 2005a, 2005b, 2006; COSEWIC 2004). Directed catches have since been reduced throughout the region due to the implementation of management practices designed to preserve shark stocks (DFO 2002). All species have been reported as incidental catch in numerous fisheries, and are occasionally brought ashore (Lien *et al.* 1982, 1984, 1985, 1986, 1987; 1989, 1990).

Historically, basking sharks were caught regularly in cod and capelin traps and gillnets, similar to humpback whales (Lien 1979; Lien and Fawcett 1986; Lien *et al.* 1982, 1984, 1985, 1986, 1987, 1988; 1989, 1990, 1994, 1995). Although the large oily livers of basking sharks were commercially valuable, there does not appear to have ever been a directed fishery on this species in Newfoundland, although the species was targeted in other areas (ICES 1995; Castro *et al.* 1999). The species is presently only captured incidentally.

Spiny dogfish were considered a nuisance species until recently, but currently a fishery for this species operates in the southern Gulf of St. Lawrence and off Nova Scotia. Current quotas are set at 2,500 mt while stock assessments are undertaken. The species is also incidentally caught in various types of fishing gear throughout Atlantic Canada. Their large spines can cause substantial damage to nets, making them unpopular with many fishers. The species' longevity, late age of maturation and extremely long gestation period make it highly vulnerable to overexploitation (Castro *et al.* 1999).

Other species of sharks are not captured intentionally, but may occur in some abundance as incidental catch in several fisheries. The Greenland shark and black dogfish, in particular, have been regularly reported as incidental catch in numerous offshore fisheries, including those for Greenland halibut, although the effect of these catches on their populations is not known at present due to lack of abundance estimates. Greenland shark have also occasionally been reported as incidental catch in nearshore gillnets (Lien *et al.* 1986; 1989; 1990a). These species, as well as other deepwater species, may be especially vulnerable to overexploitation (Kiraly *et al.* 2003).

7.1.4 - Bony Fish

This category includes a number of medium- to large-sized species of bony fish that occurred as incidental catches in gillnet fisheries off Newfoundland and Labrador, although they are not considered to be the target species of the fishery in question. This includes Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus* Mitchill), Ocean sunfish (*Mola mola* L.) and various species of billfish (family Istiophoridae).

The ocean sunfish is a pelagic species occurring throughout temperate and tropical regions of the world's oceans. In Atlantic Canada, the species approaches the northern boundary of its distribution. It is a seasonal visitor to Newfoundland and Labrador waters, associated with warm summer waters (Scott and Scott 1988). Globally, the species is often captured as incidental catch in fishing operations, but can often be released alive, although the subsequent survival rate of the individuals involved is unknown (Silvani *et al.* 1999; Cartamil and Lowe 2004). Global abundance of the species is also unknown, and little research has been conducted on this species in the past; however, the species is not presently thought to be at risk of extinction (Froese and Pauly 2006). In Newfoundland and Labrador waters, the species has occasionally been reported as an incidental catch in various fishing gears.

The Atlantic sturgeon occurs in various rivers and adjacent continental shelf waters along the east coast of North America from the Lake Melville area, Labrador, southward to Florida, including the Gulf of St. Lawrence (NMFS 1998). It is an anadromous species that has been depleted by historic overfishing, overharvesting of mature females for their caviar, modifications of their spawning habitat and pollution (NMFS 1998; Williamson 2003). It is unknown if the species spawns in Newfoundland rivers. It has been reported in Labrador, but it is also not known if the species spawns there (Anonymous, 2001). Seasonal aggregations of juveniles have been reported by fishers from the Bonne Bay area, as well as from Gilbert Bay, Labrador (Alcock *et al.* 2003; B. Hooper, MUN, pers. comm.). Based on limited information, the nearest known significant spawning areas are the St. Lawrence estuary, Quebec, and the St. John estuary, New Brunswick (NMFS 1998). It is unknown how sturgeons are distributed in marine waters of Newfoundland and Labrador although it has been assumed that the species is seasonally present, as juveniles undertake extensive migrations after they reach marine waters (Scott and Scott 1988). No commercial fishery for sturgeons exists in Newfoundland and Labrador, but the species has occasionally been reported as an incidental catch in gillnets (Lien *et al.* 1986; Ledwell and Huntington 2004).

The shortnose sturgeon (*A. brevirostrum* Lesueur), a related species, has been reported in freshwater and estuarine environments along the east coast of North America from the St. John river (New Brunswick) south to northern Florida. It is smaller and more closely associated with fresh water, and considered to be even more seriously depleted than *A. oxyrinchus* (Williamson 2003). It seems unlikely that this species would be present in coastal waters of Newfoundland. It has therefore been assumed that all instances of catches of sturgeons in Newfoundland fisheries involve Atlantic sturgeons.

Finally, billfish (family Istiophoridae) are medium- to large-bodied, active pelagic predators that occur in all tropical and subtropical waters of the world. Five species are known to occur in the northwest Atlantic ocean, and several of these are seasonal summer visitors to Atlantic Canadian waters, including Newfoundland and Labrador (Scott and Scott 1988). These include the swordfish (*Xiphias gladius* L.), Atlantic white marlin (*Tetrapturus albidus* Poey) and Atlantic sailfish (*Istiophorus albicans* Latreille). Of these, the most commonly observed species is the swordfish, which occurs seasonally in offshore waters off Nova Scotia and southern Newfoundland, and supports a local longline fishery in the Flemish Cap area (NAFO Division 3M) and the shelf edge off the Grand Banks (NAFO Division 3LN). A small but unquantified amount of incidental catch is thought to occur in other fisheries in the area, including those using gillnets.

7.2 - Methods

Methodologies used to estimate incidental catch were described in detail in Chapters 3 and 4. Fisheries under review were also identical to those described in Chapters 3 and 4. Incidental catch estimation analyses were performed at the geographic scale of coastlines, because it is unlikely that sharks either restrict themselves to a single NAFO unit or are distributed uniformly around the island of Newfoundland.

7.2.1 –Identification of Shark Species

Many shark species appear alike at first glance, and there was the potential for incorrect identification of some species, particularly among the various species of dogfish and the large pelagic sharks. Bycatch collectors were given identification sheets to help facilitate their identifications. However, it is possible that some sharks were misidentified by Collectors. Bycatch Observers received detailed information on the distinguishing characteristics of different shark species during the course of their training, and were considered familiar with the most commonly observed species (D. Kulka, DFO-NL, pers. comm.). It is considered highly unlikely that any of the bony fish under consideration here would be mistaken for another species by either Bycatch Collectors or Bycatch Observers.

7.2.2 – Reporting of Shark Incidental Catch

Bycatch Collector data were reported as the total number of sharks captured. However, Fishery Observer data had to be adjusted to generate comparable estimates of numbers of incidentally caught sharks. Observers only reported the total discarded weight of the sharks without recording the number of animals involved, which led to uncertainty regarding the total numbers of sharks caught incidentally in these fisheries. This was particularly problematic with schooling species such as spiny dogfish or Greenland shark. Reported weights were combined with length-weight ratios and maximum length data from

Fishbase (Froese and Pauly 2006) to estimate the minimum number of sharks involved. Multipliers used were 4.5 kg/individual for black dogfish, spiny dogfish, Portuguese shark and deepsea catshark (based on length-weight relationships of spiny dogfish), and 750 kg/individual for Greenland shark (the maximum reported weight), to a minimum of 1 individual. Recorded capture weights of other species were sufficiently low to assume that they involved a single animal, and this was always assumed in order to provide a minimum estimate of incidental catch. However, it is acknowledged that this method can only provide a very rough estimate of the total number of sharks caught in various fisheries. Fishery Observers need to be required to note the number of individuals involved in incidental catch events, particularly when dealing with small schooling sharks such as spiny dogfish.

7.3 - Results

7.3.1 - The Nearshore and Offshore Cod Fishery

Only small numbers of sharks were reported by Bycatch Collectors in the nearshore cod fishery (Table 7.1). The only identified species were blue sharks and basking sharks. An estimated 306 blue sharks (95% C.I.: 0-919) were caught in nearshore waters off the south coast in the third and fourth quarter of 2001 (Table 7.5). An estimated 429 basking sharks (95% C.I.: 64-941) were reported captured off the northeast coast during the third quarter of 2001. These species were not recorded in later years or other areas. An estimated 2 unidentified sharks (95% C.I.: 0-6) were caught in the third quarter of 2001 off the west coast, while an additional estimated 228 unidentified sharks (no C.I. available) were reported during the second and third quarter of 2003 off the south coast (Table 7.5).

Data from Fishery Observers generally reflect this trend (Tables 7.6, 7.7, 7.8). Catches of porbeagle sharks occurred annually in small numbers, and it is estimated that total catches over the three-year period may have been as high as 341 sharks (95% C.I.: 0-1,023). Blue and shortfin mako sharks were only reported in 2002, with an estimated catch of 263 sharks (95% C.I.: 0-798) of both species. No basking shark catches were reported.

A single thresher shark (*Alopias vulpinus* Bonnaterre) was reported in nearshore waters off the south coast in 2003. Thresher sharks are not considered regular in Newfoundland waters, but occasionally stray northward into the area (Scott and Scott 1988). If this record is extrapolated, it would indicate a catch of approximately 215 thresher sharks (95% C.I.: 0-645) in 2003 (Table 7.8).

Bycatch Collectors also record the presence of “dogfish” in their catches, although this was an uncommon occurrence (Table 7.1). Most reports came from the south coast, but occasionally from the northeast and west coasts. It was assumed that the vast majority of these records referred to the spiny dogfish. An estimated 856 spiny dogfish were captured in 2001, 3,042 in 2002, and 628 in 2003, most of which were caught along the south coast (Table 7.5).

Fishery Observer data confirmed regualr catches of spiny dogfish in the nearshore cod fishery (Tables 7.2, 7.3, 7.4). A total of 739 kg of spiny dogfish was reported by Fishery Observers during 2001-2003, leading to an estimated catch of approximately 10.7 mt spiny dogfish (95% C.I.: 3.8-19.7 mt) in 2001, approximately 113.6 mt (95% C.I.: 13.7-280.1 mt) in 2002, and approximately 28.2 mt (95% C.I.: 8.7-52.4 mt) in 2003, all along the south coast (Tables 7.6, 7.7, 7.8). An estimated total of 2,373 (95% C.I.: 855-4,385), 25,243 (95% C.I.: 3,038-62,247) and 6,275 (95% C.I.: 1,932-11,642) spiny dogfish were captured in these three years (Froese and Pauly 2006).

Black dogfish was also reported along the south coast in 2001, but was far less abundant than spiny dogfish (Table 7.2). Only 15 kg of black dogfish was reported by Fishery Observers in 2001, leading to an average estimated catch of 933 kg (95% C.I.: 116-2,276 kg; Table 7.6). This leads to an estimated minimum catch of 209 black dogfish (95% C.I.: 26-506; Froese and Pauly 2006) in 2001.

Fishery Observers occasionally reported large pelagic sharks catches in the offshore cod gillnet fishery off the south coast (Tables 7.2, 7.3, 7.4). Basking sharks were rarely captured, leading to an estimated catch of only 6 sharks (95% C.I.: 0-19) during 2002. Several porbeagles were captured each year, with an estimated catch of approximately 58 sharks (95% C.I.: 15-118) in 2001, 6 (95% C.I.: 0-19) in 2002, and 4 (95% C.I.: 0-13) in 2003 (Tables 7.6, 7.7, 7.8). Shortfin mako sharks were not reported in 2001, but total estimated catches were 6 (95% C.I.: 0-19) in 2002 and 164 (95% C.I.: 43-318) in 2003. Blue sharks were not recorded in 2001, but an estimated 26 sharks (95% C.I.: 6-51) were caught in 2002 and another 22 (95% C.I.: 4-44) in 2003. Spiny dogfish was an uncommon incidental catch in this fishery, with only 25 kg being reported by Fishery Observers during 2001-2003. The estimated spiny dogfish catch was 15 kg (95% C.I.: 0-44 kg) in 2001, 13 kg (95% C.I.: 0-39 kg) in 2002, and 98 kg (95% C.I.: 0-229 kg) in 2003. This was estimated to equate to 3 (95% C.I.: 0-10), 3 (95% C.I.: 0-9) and 22 (95% C.I.: 0-51) sharks (Froese and Pauly 2006).

Sturgeons were reported by Bycatch Collectors in nearshore waters along the northeast and southern Newfoundland coasts (Table 7.1). During 2001 and 2002, an estimated 292 (95% C.I.: 0-834) and 79 sturgeons (95% C.I.: 0-238) were caught along the northeast coast (Table 7.5). In 2003, reports of sturgeon incidental catch occurred along the south coast, leading to an estimated catch of 42 sturgeons (95% C.I.: 0-127). No sturgeons were reported by Fishery Observers in the nearshore and offshore cod fisheries during 2001-2003. No ocean sunfish or billfish were reported as incidental catch during 2001-2003.

7.3.2 - The Nearshore Lumpfish Fishery

No sharks were reported caught by Bycatch Collectors in this fishery, and Fishery Observers only reported spiny dogfish (Table 7.2). A total of 7 kg of spiny dogfish were caught off the south coast in 2001, leading to a total estimated amount of 634 kg spiny dogfish (95% C.I.: 0-1,904 kg), or a minimum of 141 spiny dogfish (95% C.I.: 0-423) for this year (Table 7.6; Froese and Pauly 2006). Bycatch Collectors reported rare catches of ocean sunfish in the nearshore lumpfish fishery (Table 7.1). An estimated total catch of four sunfish (95% C.I.: 0-13) were captured in 2002 off the west coast. No reports of ocean sunfish catches were available from Fishery Observers. One sturgeon was encountered by Bycatch Collectors along the south coast in the nearshore lumpfish fishery in 2003 (Table 7.1). Based on this record, an estimated six sturgeons (95% C.I.: 0-19) would have been encountered in this area during 2003. No sturgeons were reported by Fishery Observers in the nearshore lumpfish fishery during 2001-2003. Billfish were not reported as incidental catch during 2001-2003.

7.3.3 - The Nearshore Herring Fishery

A single unidentified shark was reported by Bycatch Collectors in the third quarter of 2001 along the west coast, leading to an estimated catch of 15 unidentified sharks (95% C.I.: 0-43; Tables 7.1, 7.5). No ocean sunfish, sturgeons, or billfish were reported as incidental catch during 2001-2003.

7.3.4 - The Offshore Monkfish and Skate Fishery

Fishery Observers reported several catches of different sharks during 2001-2003 (Tables 7.2, 7.3, 7.4). Porbeagles, blue sharks and shortfin makos occurred annually, but in low numbers. An estimated 2 (95% C.I.: 0-7), 289 (95% C.I.: 0-862) and 17 (95% C.I.: 3-35) porbeagles were caught in NAFO Division 3OPs in 2001, 2002 and 2003, respectively (Tables 7.6, 7.7, 7.8). Blue and shortfin mako sharks were less common, with estimated catches of 6 (95% C.I.: 0-18) blue sharks in 2001, 11 (95% C.I.: 2-23) in 2002 and 17 (95% C.I.: 0-43) in 2003; and 8 (95% C.I.: 0-22) shortfin mako in 2001, 3 (95% C.I.: 0-9) in 2002, and 15 (95% C.I.: 3-34) in 2003. An estimated 395 basking sharks (95% C.I.: 4-1,145) were captured in 2002, with an additional 9 (95% C.I.: 0-25) in 2003. The large weight of this species, combined with the uncertainties associated with records from the Fishery Observer programme, mean that these estimates are biased to an unknown degree, more so than the other shark species. At least, this species does occur as incidental catch in this fishery. A single thresher shark was reported in 2003, leading to a small incidental catch estimate of 1 (95% C.I.: 0-4) in this year.

Spiny dogfish were also reported captured in the monkfish and skate fishery, though not in very large numbers; only 46 kg of spiny dogfish was reported by Fishery Observers during 2001-2003 (Tables 7.2, 7.3, 7.4). Catches were variable and appeared to depend greatly on the presence of large schools of spiny dogfish near fishing gear. An estimated total of 95 kg (95% C.I.: 13-234 kg) of spiny dogfish was captured in 2001, 3,278 kg (95% C.I.: 21-9,341 kg) in 2002, and a further 37 kg (95% C.I.: 0-20 kg) in 2003, corresponding to approximately 21 (95% C.I.: 3-52), 729 (95% C.I.: 5-2,076) and 8 (95% C.I.: 0-24) specimens (Tables 7.6, 7.7, 7.8; Froese and Pauly 2006).

Black dogfish were rare catches in this fishery, with only 39 kg reported by Fishery Observers during 2001-2003 (Tables 7.2, 7.3, 7.4). This corresponded to estimates of 4 kg of black dogfish (95% C.I.: 0-12 kg) in 2001, 41 kg (95% C.I.: 9-85 kg) in 2002, and 37 kg (95% C.I.: 0-110 kg) in 2003, or a minimum of 1 (95% C.I.: 0-3), 9 (95% C.I.: 2-19) and 8 (95% C.I.: 0-24) black dogfish (Tables 7.6, 7.7, 7.8; Froese and Pauly 2006).

A total of 2,736 kg of Greenland shark was reported caught by Fishery Observers, all but 2 kg in 2002 (Tables 7.2, 7.3). This equated to estimates of 8.0 kg (95% C.I.: 0-22.6 kg) in 2001 and 10,291.5 kg (95% C.I.: 0-25,669.7 kg) in 2002 (Tables 7.6, 7.7). A minimum estimate of 1 and 14 (95% C.I.: 0-34) Greenland sharks were captured in 2001 and 2002 (Froese and Pauly 2006).

No billfish were reported as incidental catch by Fishery Observers during 2001 and 2003, but five catch events involving swordfish were reported in 2002 (Tables 7.2, 7.3, 7.4). . Based on these data, it is estimated that a total of 17 swordfish (95% C.I.: 2-37) were caught in this year (Table 7.7). No ocean sunfish or sturgeons were reported as incidental catch in the monkfish and skate fishery during 2001-2003.

7.3.5 - The Offshore White Hake Fishery

Fishery Observers reported several instances where sharks were inadvertently caught in this fishery (Tables 7.2, 7.3, 7.4). The vast majority of these involved spiny dogfish. This species was reported regularly but in small numbers (only 255 kg during 2001-2003). Based on these records, an estimated 381 kg (no 95% C.I. available) was caught in 2001, 1,175.7 kg (95% C.I.: 786.4-1,606.0 kg) in 2002, and 119.4 kg (95% C.I.: 20.2-248.8 kg) in 2003, approximately equivalent to 85, 261 and 27 specimens (Tables 7.6, 7.7, 7.8; Froese and Pauly 2006). A single blue shark was reported caught in 2002, leading to an estimated catch of 5 (95% C.I.: 0-17) blue sharks this year. Few black dogfish (approximately 2 kg) were captured in 2003, leading to an estimate of 13 kg black dogfish (95% C.I.: 0-40 kg), or approximately three individuals (95% C.I.: 0-9; Froese and Pauly 2006). Only 20 kg of Greenland shark was reported in 2001, leading to an estimated catch of 282.3 kg (no 95% C.I.

available), and a minimum of one Greenland shark caught this year. A single thresher shark was reported in 2002, resulting in a small estimated catch of 6 (95% C.I.: 0-17) thresher sharks this year.

Small numbers of swordfish were reported each year during the period 2001-2003 by Fishery Observers (Tables 7.2, 7.3, 7.4). An estimated 14 (no 95% C.I. available), 11 (95% C.I.: 0-28) and 7 (95% C.I.: 0-20) swordfish may have been captured in the offshore component of this fishery in 2001, 2002 and 2003 (Tables 7.6, 7.7, 7.8). Based on these data, the white hake fishery appears to catch a small number (10-20) of swordfish annually. No ocean sunfish or sturgeons were reported during 2001-2003.

7.3.6 - The Nearshore and Offshore Greenland Halibut Fishery

The sharks encountered in the Greenland halibut fishery were typically benthic sharks from deeper waters, likely due to the concentration of effort in these areas (Table 7.1, 7.2, 7.3, 7.4). Spiny dogfish were reported once by a single Bycatch Collector in nearshore waters along the south coast in 2002, leading to an estimated total catch of nine spiny dogfish in this area (95% C.I.: 0-31; Table 7.5). A single unidentified shark was reported in by bycatch collectors along the west coast in 2001, leading to an estimated 138 unidentified sharks caught (no 95% C.I. available). No other sharks were reported by the Bycatch Collectors in this fishery. The only sharks reported by Fishery Observers in nearshore waters were small amounts of spiny dogfish off the northeast coast in 2001 (2 kg) and off the south coast in 2003 (5 kg), leading to estimated catches of 43 kg (95% C.I.: 0-123 kg) and 361 kg (95% C.I.: 0-1,092 kg, or 9 (95% C.I.: 0-27) and 80 (95% C.I.: 0-243) individuals (Tables 7.6, 7.7, 7.8).

In the offshore component of this fishery, small numbers of basking sharks were reported caught by Fishery Observers in 2001 and 2002 (Tables 7.2, 7.3, 7.4). An estimated 24 basking sharks (95% C.I.: 0-71) were captured in 2001, and an additional 73 (95% C.I.: 9-166) in 2002. Small numbers of porbeagle and shortfin mako sharks were reported caught in 2003 (2; 95% C.I.: 0-7 for both species). No blue sharks were reported.

Spiny dogfish were reported in small numbers in this fishery, only in 2001 and 2002, in NAFO Divisions 2GHJ3K and 3LN (Tables 7.2, 7.3, 7.4). Catch estimates ranged from 142 kg (95% C.I.: 0-408 kg) in 2001 to 3,774 kg (95% C.I.: 1,408-6,987 kg) in 2002 (Tables 7.6, 7.7). This was estimated to correspond to 31 (95% C.I.: 0-91) and 807 (95% C.I.: 313-1,462) spiny dogfish in 2001 and 2002, respectively (Froese and Pauly 2006).

Greenland sharks were commonly reported by Fishery Observers, particularly in NAFO Divisions 2GHJ3K, 3LN and 3OPs (Tables 7.2, 7.3, 7.4). Overall, an estimated 67 mt (95% C.I.: 3.2-148.7 mt) was caught in 2001, and an estimated 157.8 mt (95% C.I.: 2.3-449.4 mt) in 2002, equating to a minimum of 91 (95% C.I.: 4-198) and 210 (95% C.I.: 3-599) individuals (Tables 7.6, 7.7, 7.8). This species was not reported in 2003.

Black dogfish was a commonly captured species in the Greenland halibut gillnet fishery, most often encountered along the shelf break off the Labrador coast (NAFO Divisions 2GHJ3K; Tables 7.2, 7.3, 7.4). An estimated 93 mt of black dogfish (95% C.I.: 10-142 mt) was caught in 2001, an estimated 21 mt (95% C.I.: 14-29 mt) in 2002, and 9 mt (95% C.I.: 5-13 mt) in 2003. This corresponded to a minimum of 20,609 (95% C.I.:2,174-31,563), 4,661 (95% C.I.: 2,997-6,499) and 1,910 (95% C.I.: 1,102-2,950) individuals in these years (Tables 7.6, 7.7, 7.8; Froese and Pauly 2006).

Other small deepwater shark species such as Portuguese shark and deepsea catshark were reported in this fishery in small numbers (Tables 7.2, 7.3). An estimated 816 kg of deepsea catshark (95% C.I.: 119-1,808 kg) was caught in 2001. An estimated 378 kg of Portuguese shark (95% C.I.: 0-858 kg) was captured in 2001, and an additional 288 kg (0-695 kg) in 2002 (Tables 7.6, 7.7). Based on these estimates, a minimum of 181 (95% C.I.: 26-402) deepsea catsharks were captured in this fishery in 2001, and 84 (95% C.I.: 0-191) and 64 (95% C.I.: 0-154) Portuguese sharks captured in 2001 and 2002 (Froese and

Pauly 2006). No ocean sunfish, sturgeons, or billfish were reported as incidental catch during 2001-2003.

7.3.7 - The Nearshore and Offshore Redfish Fishery

No sharks were reported by Bycatch Collectors, but some were reported by Fishery Observers. The most commonly reported species of shark captured in this fishery was the spiny dogfish. Fishery Observers recorded this species in large numbers each year (Tables 7.2, 7.3, 7.4). An estimated 83 mt (no 95% C.I. available), 19 mt (95% C.I.: 3-47 mt) and 0.4 mt (no 95% C.I. available) of spiny dogfish was captured during 2001, 2002 and 2003, respectively, corresponding to a minimum catch of 18,470 (no 95% C.I. available), 4,245 (95% C.I.: 756-10,453) and 83 spiny dogfish (no 95% C.I. available; Tables 7.6, 7.7, 7.8; Froese and Pauly 2006).

Black dogfish was a rare catch in this fishery, with only 4 kg caught in 2002 (Table 7.3). Based on this, it was estimated that approximately 141 kg of black dogfish (95% C.I.: 0-421 kg) were caught in this fishery during 2002 (Table 7.7). This corresponded to 31 individual black dogfish (95% C.I.: 0-94).

There were occasional reports of porbeagle sharks in this fishery (Tables 7.2, 7.3). An estimated 261 porbeagles (no 95% C.I. available) were caught in 2001, and an additional 68 (95% C.I.: 0-175) in 2002 (Tables 7.6, 7.7). A single shortfin mako was reported in 2003, leading to an estimated catch of 75 sharks (no 95% C.I. available) captured during this year.

A single ocean sunfish was reported by Fishery Observers during 2003 (Table 7.4). Based on this capture, an estimated 75 ocean sunfish (no 95% C.I. available) were captured in this fishery during that year (Table 7.8). No sturgeons or billfish were reported as incidental catch in 2001-2003.

7.3.8 - The Nearshore Winter Flounder Fishery

No sharks, ocean sunfish, sturgeons or billfish were reported captured in the winter flounder fishery during 2001-2003.

7.4 - Discussion

7.4.1 - Fishing Impact on Sharks and Large Bony Fish

Incidental catch reports of sharks varied widely, and their frequency depended greatly on both the fishery and shark species. Based on the available data, it appears that the most commonly encountered species by fishers in Newfoundland gillnet fisheries is the spiny dogfish. No recent stock assessments exist for this species in Atlantic Canadian waters, so it is not possible to adequately assess the effects of these removals. However, the species exhibits slow growth and an extremely long gestation period, and stocks in the northwest Atlantic are considered to be overexploited (Castro *et al.* 1999). Studies are underway to determine the population dynamics and migration patterns of the spiny dogfish that seasonally enter Canadian waters (Campana *et al.* 2006).

Black dogfish are the most commonly encountered species in offshore fisheries, particularly the Greenland halibut fishery. Population size of this deep-water species in Newfoundland and Labrador waters is unknown, and there is also a current lack of knowledge on the species' longevity, reproductive rates and age at maturity. The impact of these removals can therefore not be adequately assessed.

The total catch estimates of the various species of large, pelagic sharks are typically on the order of several hundred individuals per year, and it is unknown how this may affect the populations of these sharks. However, all of these species are vulnerable to overfishing pressure (Scott and Scott 1988; Froese and Pauly 2006). Catch data indicate that populations of these shark species in Atlantic Canadian waters continue to be adversely affected by various fisheries (e.g. Campana *et al.* 2003, 2004, 2005a, 2005b, 2006; COSEWIC 2004). The northwest Atlantic stock of porbeagle, the only species for which abundance estimates are available, may include approximately 12,000 individuals, which represents a 90% decline since exploitation started in the 1960s (COSEWIC 2004). Under these circumstances, even low levels of incidental catch may negatively affect the recovery of such depleted species. The confidence intervals of the catch estimates are wide, indicating substantial uncertainty, but the estimates are at least indicative of continuing mortality of these species in gillnet fisheries. Such estimates should be incorporated in stock assessments to further improve management. Conservation plans are currently under consideration by the Department of Fisheries and Oceans (DFO 2001). In Canada, porbeagle sharks were classified as 'Endangered' by COSEWIC in 2001, and have been reviewed for inclusion under the Species At Risk Act (COSEWIC 2004). However, in August 2006 the federal minister of Fisheries decided to not list the porbeagle shark under SARA, citing concerns for socio-economic impacts of listing this species on sectors of the fishing industry (DFO 2006). Other shark species, such as shortfin mako and basking shark, are currently under consideration for listing under SARA, but little is known about their stock status (D. Kulka, DFO-NL, pers. comm.).

The effect of incidental catch in gillnets on populations of Greenland shark is unknown. Data on age at maturity, reproduction, and longevity are almost completely absent, and stock structure of the species is unclear. However, it is thought to be highly sensitive to overfishing, and concern appears warranted (Castro *et al.* 1999). High levels of catch have been recorded in the offshore trawl fishery for Greenland halibut in NAFO Division 0A/B (unpublished DFO data). Greenland sharks, black dogfish and other deepwater sharks likely have even lower rates of growth and reproduction than most shallow-water species due to the low productivity of their environment (Kiraly *et al.* 2003). As such, they are likely to be disproportionately impacted by deepwater fisheries, and the high mortality estimates reported here are cause for concern.

Ocean sunfish appear uncommon catches in gillnet fisheries in Newfoundland and Labrador, despite the fact that they are regularly sighted locally along the south coast by Bycatch Collectors (unpublished data). Their essentially pelagic habits may prevent them from encountering many bottom-set gillnets. Pelagic gillnets fishing for herring, which could be expected to capture ocean sunfish, are mostly concentrated in the Strait of Belle Isle (NAFO area 4Ra), but no large numbers of ocean sunfish have been reported from that area. Their distribution may be limited to waters off the south coast and the southern Gulf of St. Lawrence due to the seasonal influx of warmer water. There are no abundance estimates for this species in the north Atlantic, nor is there any information on population structure. However, based on present data, incidental catch in gillnets in Newfoundland and Labrador waters does not appear to pose a significant risk to the long-term survival of the ocean sunfish population in the north Atlantic.

The current stock status of Atlantic sturgeon in Atlantic Canadian waters is unknown, but the species is likely depleted in many areas. As such, the estimated mortality of sturgeons in Newfoundland and Labrador fishing gear between 2001-2003 may potentially delay or prevent recovery of this species despite conservation measures which are mainly aimed at restoring the species' freshwater spawning habitat (NMFS 1998). Further research into the distribution of this species in Newfoundland and Labrador waters and the potential impact of incidental catches in fishing gear is urgently required.

Of the billfish, only swordfish were reported as an incidentally captured species in the offshore fisheries for monkfish, skates and white hake during 2001-2003. Swordfish stocks in Atlantic Canadian waters are managed according to a comprehensive management plan (DFO 2004). In 2005, the International Commission for the Conservation of Atlantic Tunas (ICCAT), which also oversees swordfish quota, allocated 1,348 mt of the north Atlantic swordfish stock as the Total Allowable Catch to Canada. Based on the data available in this study, an estimated 2.1 mt of swordfish was incidentally captured in gillnets during the three-year period under consideration, or an average of 0.7 mt per year. It therefore does not appear that the gillnet fisheries discussed here currently form a significant source of additional mortality for the swordfish stock occurring in Newfoundland waters.

7.5 - Conclusions

Incidental mortality of sharks and some large bony fish in gillnet fisheries in Newfoundland and Labrador has been quantified for the first time. Based on the data reported here, catch rates of spiny dogfish are especially high, and appear to mainly occur along the south coast in nearshore fisheries for cod and redfish, and offshore fisheries for monkfish and skate. Catches of pelagic sharks such as porbeagle, blue, shortfin mako and basking shark, occur regularly in various fisheries. Catches of Greenland shark and black dogfish are largely confined to the offshore fishery for Greenland halibut, where they occur together with small numbers of several other deepwater species. Of the bony fish discussed here, only catches of Atlantic sturgeon appear substantial, occurring in nearshore fisheries for cod and lumpfish.

In most cases, the impact of this incidental mortality cannot be evaluated because stock size is unknown. However, concern is warranted given most shark populations' low resilience to overfishing. Several shark stocks in Atlantic Canadian waters are considered depleted, and additional incidental mortality in fisheries must be addressed to facilitate recovery of these species. However, there are substantial data requirements concerning life history, distribution and stock structure of most species discussed here. In the case of Atlantic sturgeon, there is an additional need to determine if the species currently spawns in the province's watersheds, to put appropriate conservation measures in place.

7.6 - References

Alcock, E., D. Ings and D.C. Schneider. 2003. From local knowledge to science and back: Evolving use of local ecological knowledge in fisheries science. Fisheries Centre Research Reports 11 (5): 20-39.

Anonymous. 2001. Fish collection database of the National Museum of Natural History (Smithsonian Institution). Smithsonian Institution - Division of Fishes.

Blank, S., C. Seiter and P. Bruce. 2001. Resampling stats in Excel. Version 2. Resampling Stats, Inc., Arlington, VA, USA.

Bonfil, R. 1994. Overview of world elasmobranch fisheries. FAO Fisheries Technical Paper 341: 119.

Campana, S.E., L. Marks, W. Joyce and N.E. Kohler. 2006. Effects of recreational and commercial fishing on blue sharks (*Prionace glauca*) in Atlantic Canada, with inferences on the North Atlantic population. Canadian Journal of Fisheries and Aquatic Science 63:670-682.

Campana, S.E., L. Marks, and W. Joyce. 2005. The biology and fishery of shortfin mako sharks (*Isurus oxyrinchus*) in Atlantic Canadian waters. Fisheries Research 73: 341-352.

Campana, S.E., L. Marks, W. Joyce, and N. Kohler. 2005. Catch, bycatch and indices of population status of blue shark (*Prionace glauca*) in the Canadian Atlantic. Col. Vol. Sci. Pap. ICCAT 58: 891-934.

Campana, S., L. Marks, and W. Joyce. 2004. Biology, fishery and stock status of shortfin mako sharks (*Isurus oxyrinchus*) in Atlantic Canadian Waters. CSAS Research Document 2004/094

Campana, S.E., W. Joyce, and L. Marks. 2003. Status of the porbeagle shark (*Lamna nasus*) population in the Northwest Atlantic in the context of "species at risk". CSAS Research Document 2003/007.

Campana, S.E., W. Joyce, and Z. Zahorodny. 2006. Canadian Shark Research Laboratory website. Last accessed on 21/07/2006. Available online at: http://www.marinebiodiversity.ca/shark/english/index.htm.

Carbonell, A., F. Alemany, P. Merella, A. Quetglas and E. Roman. 2003. The by-catch of sharks in the western Mediterranean (Balearic Islands) trawl fishery. Fisheries Research 61: 7-18.

Carretta, J.V., T. Price, D. Petersen and R. Read. 2004. Estimates of marine mammal, sea turtle, and seabird mortality in the California drift gillnet fishery for swordfish and thresher shark, 1996-2002. U S National Marine Fisheries Service Marine Fisheries Review 66 (2): 21-30.

Cartamil, D.P. and C.G. Lowe. 2004. Diel movement patterns of ocean sunfish *Mola mola* off southern California. Marine Ecology Progress Series 266: 245-253.

Casey, J.M. and R.A. Myers. 1998. Near extinction of a large, widely distributed fish. Science 281: 690-692.

Castro, J.I., C.M. Woodley and R.L. Brudek. 1999. A preliminary evaluation of the status of shark species. FAO Fisheries Technical Paper 380: 72 pp.
COSEWIC. 2004. COSEWIC assessment and status report on the porbeagle shark *Lamna nasus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON: vii + 43. Available online at: http://www.-sararegistry.gc.ca/virtual_sara/files/cosewic/sr%5Fporbeagle%5-Fshark%5Fe%2Epdf.
COSEWIC. 2006. Species search. Committee on the Status of Endangered wildlife in Canada website. Accessed on 21/07/2006. Available online at: www.cosewic.gc.ca.
DFO [Department of Fisheries and Oceans]. 2001. Canadian Atlantic pelagic shark integrated fishery management plan. Department of Fisheries and Oceans, Ottawa, ON, Canada. Available online at: http://www.-marinebiodiversity.ca/shark/english/document/2002-2007%-20SHARK%20management%20Plan.pdf.
DFO [Department of Fisheries and Oceans]. 2002. Canadian Atlantic pelagic shark integrated fisheries management plan 2002-2007. Department of Fisheries and Oceans, 50 pp. Available online at: www.dfo-mpo.gc.ca.
DFO [Department of Fisheries and Oceans]. 2003. Atlantic Seal Hunt 2003-2005 Management Plan. Department of Fisheries and Oceans, Ottawa, ON, Canada. Available online at: http://www.dfo-mpo.gc.ca/seal-phoque/reports-rapports/mgtplan-plangest2003/mgtplan-plangest2003_e.htm#14.
DFO [Department of Fisheries and Oceans]. 2004. Canadian Atlantic swordfish and other tunas 2004-2006 integrated management plan. Available online at: http://www.dfo-mpo.gc.ca/communic/fish_man/ifmp/swordfish/-index_e.htm?template=print.
DFO [Department of Fisheries and Oceans]. 2006. Forty-two Species Added for Protection Under the Species at Risk Act. DFO News Release, August 24, 2006. Available online at http://www.ec.gc.ca/press/2006/-060824_n_e.htm.
Diaz, G.A. and J.E. Serafy. 2005. Longline-caught blue shark (*Prionace glauca*): factors affecting the numbers available for release. Fishery Bulletin 103: 720-724.
Efron, B. and R.J. Tibshirani. 1993. An introduction to the Bootstrap. Chapman and Hall, New York, USA.
FAO [Food and Agriculture Organization of the United Nations]. 1998. International Plan of Action for the Conservation and Management of Sharks. Document FI:CSS/98/3, Rome.
FAO [Food and Agriculture Organization of the United Nations]. 2004. The State of World Fisheries and Aquaculture (SOFIA) 2004. United Nations Food and Agriculture Organisation (FAO), Rome, IT: 153. Available online at: http://www.fao.org/sof/sofia/index_en.htm.

Froese, R. and D. Pauly. 2006. FishBase electronic database. Available online at: www.fishbase.org.
Hurley, P.C.F. 1998. A review of the fishery for pelagic sharks in Atlantic Canada. Fisheries Research 39: 107-113.
ICES [International Council for the Exploration of the Sea]. 1995. Report of the study group on elasmobranch fishes. ICES cm 1995/g:3. ICES Headquarters, Copenhagen. 92 pp.
IUCN [International Union for the Conservation of Nature]. 2006. 2006 IUCN Red List of Threatened Species. Available online at: www.iucnredlist.org
Kiraly, S.J., J.A. Moore and R.H. Jasinski. 2003. Deepwater and other sharks of the U.S. Atlantic Ocean Exclusive Economic Zone. Marine Fisheries Review 65 (4): 1-63.
Ledwell, W., and J. Huntington. 2004. Marine Animal entrapments in fishing gear in Newfoundland and Labrador and a summary of the Whale Release and Strandings Programme during 2004. A report to the Department of Fisheries and Oceans, St. John's, NL, Canada: 22 pp.
Lewison, R.L., L.B. Crowder, A.J. Read and S.A. Freeman. 2004. Understanding impacts of fisheries bycatch on marine megafauna. Trends in Ecology and Evolution 19 (11): 598-604.
Lien, J. 1979. Whale collisions with fishing gear in Newfoundland. A Progress Report to the Ministers Committee on Whales and Whaling. Memorial University of Newfoundland, 40 pp.
Lien, J., K. Breeck, D. Pinsent and H. Walter. 1986. Whale and shark entrapments in inshore fishing gear during 1986: A preliminary report in Fisheries and Oceans Canada. Department of Fisheries and Oceans Canada, 1-33.
Lien, J., L. Dix, E. Lee and H. Walters. 1984. Whale and shark entrapments in inshore fishing gear during 1984: A preliminary report in Fisheries and Oceans Canada. N.I.C.O.S. Contribution No. 79: 21 pp.
Lien, J., and L. Fawcett. 1986. Distribution of basking sharks, *Cetorhinus maximus*, incidentally caught in inshore fishing gear in Newfoundland. Canadian Field-Naturalist 100(2): 246-252.
Lien, J., J.H. Dong, L. Baraff, J. Harvey and K. Chu. 1982. Whale entrapment in inshore fishing gear during 1982: a preliminary report to Fisheries and Oceans Canada, September 20, 1982. Newfoundland Institute for Cold Ocean Science; Canada. Dept. of Fisheries and Oceans. Newfoundland Region, 36 pp.
Lien, J., J. Huntington, W. Ledwell, and T. Huntsman. 1990. Whale entrapments in inshore fishing gear and a summary of the entrapment assistance programme in Newfoundland and Labrador during 1990. A preliminary report to the fisheries Development Branch of the Department of Fisheries and Oceans, and the Newfoundland and Labrador Department of Fisheries. Memorial University of Newfoundland, 37 pp.

Lien, J., W. Ledwell and J. Nauen. 1988. Incidental entrapments in fishing gear during 1988: a preliminary report to the Newfoundland and Labrador Department of Fisheries and Oceans, Newfoundland Region. Memorial University of Newfoundland, 27 pp.

Lien, J., J. Papineau and L. Dugan. 1987. Incidental entrapments of cetaceans, sharks and marine turtles in inshore fishing gear reported during 1987 in Newfoundland and Labrador. A preliminary report submitted to the Department of Fisheries and Oceans and the Newfoundland and Labrador Department of Fisheries. Memorial University of Newfoundland, St. John's, NL, Canada: 44 pp.

Lien, J., D. Pittman, C. Hood, C. Richter, D. Borggaard, F. Marques and S. Todd. 1995. Entrapments in fishing gear and strandings in Newfoundland and Labrador reported to the Entrapment Assistance Programme during 1994. A report to the Department of Fisheries and Oceans and the Atlantic Fisheries Adjustment Program. Memorial University of Newfoundland, St. John's, NL, Canada: 27 pp.

Lien, J., D. Pittman and D. Mitchell. 1994. Entrapments in fishing gear and strandings in Newfoundland and Labrador reported to the Entrapment Assistance Programme during 1993, and preliminary reports on the impact of acoustic deterrents on the incidental catches of Harbour Porpoise in fixed fishing gear. A report to the Department of Fisheries and Oceans and the Atlantic Fisheries Adjustment Program. Memorial University of Newfoundland, 17 pp.

Lien, J., G.B. Stenson and I. Hsun-Ni. 1989. A review of incidental entrapment of seabirds, seals and whales in inshore fishing gear in Newfoundland and Labrador: a problem for fishermen and fishing gear designers. Proceedings of the 1988 World Symposium on Fishing Gear and Fishing Vessel Design, Newfoundland and Labrador Institute of Fisheries and Marine Technology, St. John's, NF 67-71.

Lien, J., H. Walter and C. Harvey-Clark. 1985. Whale and shark entrapments in inshore fishing gear during 1985: A preliminary report to Fisheries and Oceans Canada. 22 pp.

NMFS [National Marine Fisheries Service]. 1998. Status review of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*). National Marine Fisheries Service Status Report. 133 pp.

Scott, W. B.and M.G. Scott. 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 219: 731 pp.

Shepherd, T.D. and R.A. Myers. 2005. Direct and indirect fishery effects on small coastal elasmobranchs in the northern Gulf of Mexico. Ecology Letters 8: 1095-1104.

Silvani, L., M. Gazo and A. Aguilar. 1999. Spanish driftnet fishing and incidental catches in the western Mediterranean. Biological Conservation 90 (1): 79-85.

Simon, J.L. 1997. Resampling: The New Statistics, Resampling Stats, Inc., Arlington, VA, U.S.A.
Simpfendorfer, C.A. 2000. Predicting population recovery rates for endangered western Atlantic sawfishes using demographic analysis. Environmental Biology of Fishes 58: 371-377.
Sims, D.W., A.M. Fox and D.A. Merrett. 1997. Basking shark occurrence off south-west England in relation to zooplankton abundance. Journal of Fish Biology 51: 436-440.
Sims, D.W. and V.A. Quayle. 1998. Selective foraging behaviour of basking sharks on zooplankton in a small-scale front. *Nature* 393: 460-464.
Stevens, J.D., R. Bonfil, N.K. Dulvy and P.A. Walker. 2000. The effects of fishing on sharks, rays, and chimaeras (Chondrichthyans), and the implications for marine ecosystems. ICES Journal of Marine Science 57 (3): 476-494.
Templeman, W. 1966. Marine resources of Newfoundland. Fisheries Research Board of Canada Bulletin 154: 170.
Thorson, T.B. 1982. The impact of commercial exploitation on sawfish and shark populations in Lake Nicaragua. Fisheries 7: 2–10.
Walker, T.I. 1998. Can shark stocks be harvested sustainably? A question revisited with a review of shark fisheries. Marine and Freshwater Research 49: 553-572.
Williamson, D.F. 2003. Caviar and Conservation: Status, Management and Trade of North American Sturgeon and Paddlefish. TRAFFIC North America, World Wildlife Fund, Washington, D.C., U.S.A.: 252. Available online at: www.traffic.org.

CHAPTER 8 - INCIDENTAL CATCH OF LARGE MARINE VERTEBRATES: MANAGEMENT IMPLICATIONS AND RESEARCH NEEDS

8.1 - Introduction

At least 33 species of large marine vertebrates (small cetaceans, pinnipeds, seabirds, sharks, bony fish) were reported as incidental catch in commercial gillnet fisheries in Newfoundland and Labrador during 2001-2003 (Tables 4.5, 5.3-4, 6.3-5 and 7.3-8). Confidence intervals were large for many estimates, reflecting the variability in incidental catch rates among and between fishers. It is recognized that the estimates presented here depend greatly on the quality of reporting of fishing effort and incidental catch events by fishers and observers. Nonetheless, these estimates serve as an indication of the relative importance, in terms of entanglement risk, of different fisheries to various species of large marine vertebrates. In order to rectify concerns related to data collection, future concerted efforts are required to improve the quality of data available for management, in order to reduce the impact of gillnets on these large marine vertebrates. However, a current lack of information should not be perceived as a reason to delay implementation of mitigative factors to aid in cases where high levels of incidental catches have been reported (Lewison *et al.* 2004).

This chapter will provide a brief review of key findings of the incidental catch results described in Chapters 4-7. It will also review possible measures to improve monitoring for, and to reduce or prevent the occurrence of, incidental catch of large marine vertebrates in gillnet fisheries of Newfoundland and Labrador. Recommendations for future management of incidental catch of large marine vertebrates are also made as part of an ecosystem approach to fisheries.

8.2 - Review of incidental catch of large marine vertebrates in Newfoundland and Labrador gillnet fisheries

Incidental catch of large marine vertebrates occurred in all gillnet fisheries studied. However, some fisheries captured greater numbers of individuals, or a wider variety of species, than others. The nearshore gillnet fisheries for cod and lumpfish, and the offshore gillnet fishery for monkfish and skates, appeared to be the fisheries with the greatest impact on large marine vertebrates, both in terms of the diversity of species caught and the large fraction of all incidental catches for species that occurred in these fisheries per unit effort (Tables 4.5, 5.3-4, 6.3-5 and 7.3-8). The nearshore fishery for cod captured large numbers of a wide variety of species, particularly small cetaceans, seabirds, seals and sturgeons.

Sharks were comparatively uncommon in this fishery. The lumpfish fishery is well known for its substantial catch rates of harp seals and other seal species (Walsh *et al.* 2000). This fishery also caught large numbers of seabirds (murres, loons) and small numbers of harbour porpoise, spiny dogfish and sturgeons. Finally, the offshore fisheries for monkfish and skates reported relatively high catches of harbour porpoise and various dolphins, shearwaters and a wide variety of shark species, as well as small numbers of seals and swordfish. The comparatively high levels of Fishery Observer coverage in this fishery are likely responsible for this detailed assessment of incidental catch.

Offshore fisheries for cod, Greenland halibut and white hake captured a wide range of species, and some of these incidentally-captured species occurred in substantial numbers (Tables 4.5, 5.3-4, 6.3-5 and 7.3-8). The offshore cod fishery off the south coast captured mainly large pelagic sharks (porbeagle, blue, shortfin mako) and seabirds (many shearwaters, as well as small numbers of murres), with limited catches of seals. The Greenland halibut fishery captured large numbers of different species of sharks and shearwaters, as well as small numbers of seals (harp seal) and small cetaceans (harbour porpoise). This fishery was mainly concentrated in deeper waters along the shelf edge and could therefore capture deepwater shark species, which are potentially vulnerable to overexploitation (Kiraly *et al.* 2003). The white hake fishery captured small numbers of sharks, shearwaters and small cetaceans (harbour porpoise, but potentially also dolphins), as well as swordfish. This fishery was mostly concentrated in a small area along the shelf edge off the south coast of the island, which may have limited its overall impact. It was otherwise comparable to the offshore fishery for monkfish and skates in terms of the diversity of species impacted.

Large numbers of spiny dogfish and several other shark species were captured in the redfish fishery, but few other species were caught (Tables 4.5, 5.3-4, 6.3-5 and 7.3-8). This fishery is restricted to the south coast, and it is thought that this limited distribution may have prevented a wider range of other species getting caught. The winter flounder fishery typically takes place in shallow nearshore waters, and this may well be the reason why many species, including small cetaceans and sharks, were not captured in these nets. This fishery only caught small numbers of seabirds (loons, murres, gannets) and seals (mainly harp seals).

The nearshore herring fishery only reported occasional incidental catches of harbour porpoise, making this the fishery with the lowest apparent impact per unit of fishing effort on large marine vertebrates in terms of direct mortality and diversity of affected species (Tables 4.5, 5.3-4, 6.3-5 and 7.3-8). This is a geographically-localized fishery using pelagic nets with a small mesh size. It is possible that many larger species are less prone to entanglement in these nets, but further research is necessary to determine if this is the case. However, the coverage in this fishery (by means of Bycatch Collectors) was low, and no Fishery Observer data were available.

This thesis examined the potential impacts of incidental catch of a wide variety of large marine vertebrates in different gillnet fisheries in Newfoundland and Labrador. Incidental catch estimates for different species were provided in Chapters 4, 5, 6 and 7 (Tables 4.5, 5.3-4, 6.3-5 and 7.3-8). Overall, catch estimates varied widely between species, with some (e.g. harp seals) being reported in large numbers, while others (e.g. ocean sunfish) appeared to get caught only occasionally. For some species, (e.g. murres, sturgeons) the incidental mortality in gillnets may affect local populations, while for others (e.g. harp seals) current level of catches appears insignificant relative to population sizes.

For most species discussed here, insufficient information exists to adequately assess the impact of this anthropogenic mortality. There is a need for current information on abundance, distribution, life history and migratory movements of the species discussed. Reliable abundance estimates are the most important of these data needs, because these will allow the calculation of the mortality rate (numbers of individuals killed as a fraction of the total population) for a first assessment of the potential impact that incidental mortality in gillnets might have on the species in question. Subsequently, the species' distribution at various geographic and temporal scales, and possible migratory pathways, should be determined to identify areas of potential critical habitat for the species. Such an assessment is the first step in the development of a practical long-term management strategy that will maintain and rebuild populations of these species in Canadian waters. This strategy should incorporate mortality rate estimates from a wide range of industries, such as various fisheries, directed hunting, offshore hydrocarbon extraction, pollution, and other potential limiting factors for these species.

Estimating abundance of large vertebrates, such as marine mammals, sharks and seabirds can be complicated, because the animals range over large areas and are often difficult to detect. Visual surveys can record abundance of marine mammals and seabirds in a representative area, which can then be extrapolated to a larger region, although care must be taken in designing the survey that representative areas are covered (Camphuysen *et al.* 2004). Such surveys require good visibility and specific assumptions about sighting probabilities of species at different distances from the survey platform (Palka 2006). Sharks and other fish cannot reliably be detected using surface-based visual surveys. Acoustic surveys can identify presence or absence of cetaceans, but their effectiveness depends on the intensity of cetacean vocalizing activity, and they are not useful in detecting species that do not vocalize, such as sharks.

For such species, incidental catch records in fisheries may provide more helpful information. Catch data of sharks from different fisheries can be used to estimate changes in relative abundance, if a sufficiently large dataset is available (Simpfendorfer *et al.* 2000).

A management plan for gillnet fisheries in Newfoundland and Labrador that takes account of incidental mortality of non-target species (specifically, species that are not commercially targeted fish species) is long overdue, and should be developed in collaboration with the fishing industry and other stakeholders. A number of changes could be made to the current Bycatch Collector and Fishery Observer programmes to improve the data collection process and data quality (see suggestions in Section 8.4). Several methodologies currently exist to reduce or prevent incidental catch from occurring, and these are discussed below. Finally, prospective changes in the current management regime are discussed, from the perspective of an ecosystem approach.

8.3 - Potential Mitigation Measures to Prevent Incidental Catch

Methods to reduce or prevent incidental catches of large marine vertebrates in gillnets generally fall into two categories. One methodology focuses on reducing opportunities for inadvertent catches by means of changes to fishing gears and methods, as well as temporary time-area closures, while the other attempts to alert the animals to the presence of the nets before entanglement occurs (Hoyt 2005; IWC 1994; Kraus *et al.* 1997; Melvin and Parrish 2001; Murawski *et al.* 2000; Trippel *et al.* 2003). These methods are not mutually exclusive, and management agencies should carefully consider the relative merits of a variety of potential mitigation measures before deciding on their possible implementation. Best results may be achieved by following a comprehensive plan that includes several different approaches with clearly defined goals that can be independently verified. Including representatives of the fishing industry in the decision-making process increases the likelihood of ultimate success (Melvin and Parrish 2001).

8.3.1 - Time-Area Closures

Periodic closures of specific areas have been used in numerous fisheries in many parts of the world as a means to prevent incidental catch of non-target species, to allow recovery of depleted stocks, or to protect spawning aggregations (Murawski *et al.* 2000; Pitcher *et al.* 2000). In recent years, the idea of time-area closures has developed into the concept of Marine Protected Areas (MPAs) where specific locations are formally placed under a year-round conservation regime to protect vulnerable habitats and associated species against human exploitation; this conservation regime may lead to reductions in, or bans on, fishing effort (IUCN 1999; Dayton *et al.* 2000; Hyrenbach *et al.* 2000;

Sumaila *et al.* 2000; Russ and Alcala 2004). Marine Protected Areas can be considered a form of insurance for future catastrophic events, either anthropogenic or environmentally driven, that might lead to widespread collapse of fish stocks. MPAs can conserve fragile marine habitats and biodiversity, maintain ecosystem structure, and serve as a baseline to compare management of other areas. Finally, they may allow depleted populations to rebuild and recolonise adjacent areas, where they may become available to the fishing industry (e.g. Lauck *et al.* 1998; IUCN 1999; Sumaila *et al.* 2000; Roberts *et al.* 2001; Gell and Roberts 2003; Murawski *et al.* 2000, 2004). Most Marine Protected Areas have been established in tropical waters, but increasing numbers are now being put in place in temperate and boreal marine ecosystems (Auster and Shackell 2000; Garcia-Charton *et al.* 2000; Jamieson and Levings 2001; Russ and Alcala 2004; Tissot *et al.* 2004; McClanahan and Graham 2005).

Closing areas to exploitation has also been used for the conservation of stocks of marine mammals by bodies such as the International Whaling Commission that designated the Indian Ocean Sanctuary in 1979 and the Southern Ocean Sanctuary in 1994 as conservation mechanisms for large cetaceans (IWC 1980, 1995). In the case of small cetaceans, areas closed to fishing activities have been established as part of comprehensive management schemes in several areas, including the Gulf of Maine (United States) for harbour porpoise, the Gulf of California (Mexico) for vaquita, the Gully underwater canyon system off the coast of Nova Scotia (Canada) for northern bottlenose whales, and the Banks Peninsula (New Zealand) for Hector's dolphin (Richter 1998; Hooker *et al.* 1999; Hughey 2000; Murray *et al.* 2000; Reeves 2000; Hood 2001; Hoyt 2005).

Pinnipeds have mainly benefited from protection of rookeries or haul-out sites from direct exploitation, but pinniped feeding areas in the open ocean are often unknown and unprotected. Seabird colonies may receive protection from direct hunting, but fishing activities may continue in the vicinity of these colonies. Feeding aggregations have been conserved in some areas (Hyrenbach *et al.* 2006). At present, no MPAs have been proposed specifically for the conservation of sharks, although populations of some tropical species with relatively sedentary habits may benefit from Marine Protected Areas in coral reef environments (DeMartini and Friedlander 2004).

Time-area closures and MPAs appear to hold promise as a conservation tool in cases (1) where the problem of incidental catch is localized in a subsection of the total area being fished, (2) where the spatio-temporal distribution pattern of the incidental catch is known and predictable, (3) where any displacement of fishing effort from within the closure does not result in an increase in incidental catch outside the closure, (4) where fishers understand and support the closure, and agree to abide by its regulations, and (5) where sufficient information exists upon which to base a closure (Murray *et al.* 2000). These conditions often remain unmet when dealing with incidental catch of large marine vertebrates. In particular, closures may be less successful in cases where species are wide-ranging in their habits, as is the case with the majority of marine mammals, seabirds, and sharks (Allison *et al.* 1998; Gell and Roberts 2003). The wide-ranging habits of many marine species, including fish, sharks and marine mammals, imply that significant areas of the marine environment may have to be closed to fisheries in order for these populations to rebuild to any meaningful extent (Lauck *et al.* 1998; Boersma and Parrish 1999; Murawski *et al.* 2000). However, smaller closures can still be effective if they include specific areas where high aggregations of these species occur periodically, such as harbour porpoise in the Bay of Fundy, or black-footed albatross off the coast of California (Waring *et al.* 2003; Hyrenbach *et al.* 2006).

The majority of currently existing MPAs are in nearshore waters, associated with fixed submerged or surface features such as reefs or islands. So far there has been little effort to implement MPAs in offshore waters, due to the large geographic scales involved, the ever-changing dynamic nature of the open ocean environment, and enforcement difficulties (Boersma and Parrish 1999). However, many species of wide-ranging large marine vertebrates would likely benefit from the closure of portions of the open ocean to fishing activity with MPAs. Such MPAs may not be fixed in place, but rather be dynamic, incorporating sections of large oceanic currents or frontal systems (Hyrenbach *et al.* 2000). These MPAs could be structured around a core water mass in which no fishing would be permitted, surrounded by a buffer area in which limited fisheries could be allowed. Remote sensing technology can be used to measure important oceanographic or biological features of the system, such as sea surface temperature or chlorophyll concentrations, and the location of MPA boundaries would then be determined on a day-to-day basis. Such information is already used by many industrialized fisheries to locate likely fishing grounds, and should become a regular part of open ocean management (Mikol 1997; Hyrenbach *et al.* 2000). However, adverse atmospheric conditions (e.g. continuous cloud cover) may reduce available data for areas such as Newfoundland and Labrador, and management based on remote sensing input should be sufficiently robust to cope with extended periods of little or no data updates.

Fisheries management plans that include time-area closures as components must also take into account interannual fluctuations in distribution of the target species that may be caused by environmental variability, indicating that the designation of closed areas by necessity will have to be a flexible process with the capability to respond rapidly to new information. Finally, fishers need to be involved in the development of time-area closures to help minimize any economic hardship brought on by closure of traditional fishing grounds. The closure of large areas to fishing as a conservation measure may lead to displacement of fishing effort toward other areas and fisheries, potentially resulting in increased fishing pressure on other species (Murray *et al.* 2000; Murawski *et al.* 2005). For this reason, fishing effort reduction should always be considered as a component of a broader management plan. However, it may prove politically impossible to close a sufficiently large area to fishing in order to significantly reduce incidental catch of small cetaceans or other species, if fishers are not included in the establishment of such a management plan.

Enforcement of time-area closures or MPAs can often be difficult, particularly when dealing with large numbers of small fishing vessels (Read 2000). In many jurisdictions around the world, larger vessels are required to carry Vessel Monitoring Systems (VMS), enabling surveillance using remote sensing technology (Molenaar and Tsamenyi 2000; Drouin 2001; Deng *et al.* 2005; Kourti *et al.* 2005). Some of these systems also allow for continuous monitoring of catch as it is being handled on deck by digital cameras, and recording of environmental parameters using sensors attached to the fishing gear (González *et al.* 2004). However, this method is not fool-proof, as evidenced by several recent cases where the use of technology enabled vessels to falsify their advertised position by several thousands of kilometres (High Seas Task Force 2006). Nonetheless, the levels of monitoring have been increasing in recent years, reflecting the increased emphasis on surveillance in offshore waters

(Molenaar and Tsamenyi 2000; High Seas Task Force 2006). This new technological capacity will also improve the management of offshore marine protected areas.

8.3.2 - Improving the Detectability of Nets

Another methodology to reduce incidental catch of large marine vertebrates in gillnets focuses on modifications of the nets to enhance their detectability by non-target marine animals. Most of the research in this field has focused on attempts to reduce incidental catch of small cetaceans, based on the observation that species such as harbour porpoise and bottlenose dolphin appear to be able to detect gillnets acoustically and, presumably, visually before getting entangled (Au and Jones 1991; Au 1994; Hatakeyama *et al.* 1994; see Chapter 1). Efforts to alert small cetaceans to the presence of gillnets have focused on one of two methods: 1) by attaching sound-producing devices to the gear to alert animals to its presence; or 2) by modifying the structure of the gear to improve the chances of it being detected by the animals before entanglement can occur.

The sound-producing devices commonly known as 'pingers' were first developed in the early 1990s by Dr. Jon Lien and colleagues at Memorial University of Newfoundland (MUN) in collaboration with nearshore fishers in an attempt to alert small cetaceans to the presence of fishing gear barriers (Lien *et* *al.* 1992, 1995). Since then, their development has been swift, and they are among the best-known methods to reduce incidental catches of small cetaceans in gillnets in current use. Generally speaking, these devices operate by periodically producing underwater sounds that are intended to either alert small cetaceans in the area to the presence of the nets, or to startle them and hopefully drive them away from the nets (Kastelein *et al.* 1995; Kraus *et al.* 1997). They are typically attached to the head rope of a fleet of gillnets in such a way that they remain above the sea floor, and are typically powered by alkaline batteries. The sounds produced by different types of modern pingers range between 2.5 and 80 kHz, with ultrasonic harmonics of some types reaching up to 160 kHz. Source levels range from 115 dB re 1μPa at 1m to 145 dB re 1μPa at 1m (Lockyer *et al.* 2001; CEC 2002b). Several pingers may be required for every net, as the main goal is to present an acoustic barrier to approaching animals (IWC 1994).

The technical design of the earliest pingers was basic, with a limited number of parts that were all easily replaceable, and thus relatively inexpensive; most importantly, they offered fishers a method to reduce the risk of losing their catch, or even facing the destruction or loss of their nets and fish traps if large whales collided with them. These traits were meant to increase the likelihood of their acceptance among fishers in small, often remote communities (Lien *et al.* 1995). Their effectiveness in reducing incidental catch of harbour porpoise in gillnet fisheries in the Bay of Fundy has been reported by various authors (Lien *et al.* 1995; Trippel *et al.* 1996; Richter 1998). More recent models of pingers have become increasingly complex with additional capabilities (Lockyer *et al.* 2001). The efficacy of these pingers has been tested in controlled experiments, and significant reductions in incidental catches of small cetaceans have been reported in several fisheries (Gearin *et al.* 1996; Kraus *et al.* 1997; Stone *et al.* 1997; Trippel *et al.* 1999; Culik *et al.* 2000; IWC 2000; Lockyer *et al.* 2001; Bordino *et al.* 2002; Carlström *et al.* 2002; Barlow and Cameron 2003). This has led to fisheries managers employing pingers as a potential solution to the problem of incidental catch of small cetaceans. The use of pingers has subsequently become mandatory in different fisheries in several jurisdictions around the world (IWC 2000; Larsen *et al.* 2002; Barlow and Cameron 2003; EC 2004). Pingers have also proven effective in reducing incidental catch of alcid seabirds under low-light conditions (Melvin *et al.* 1999). The effects of deployment of pingers on incidental catches of other large marine vertebrates (particularly sharks) presently remain unknown, and further research is required in this area.

While pingers are useful tools to prevent or reduce incidental catch of large marine vertebrates, several possible concerns have been raised about their short- and long-term usage (Dawson *et al.* 1998). Individual and species-specific behaviour patterns within and among species may influence the degree to which pingers can prevent entanglement. For example, the bottom-grubbing foraging behaviour in harbour porpoises may predispose them to incidental capture, regardless of whether or not pingers are present (Lockyer *et al.* 2001). It has been suggested that small cetaceans, in particular, might be excluded from significant portions of their habitat by the widespread application of pingers. Based on observations of various species of small cetaceans around pingers in wild and captive settings, the displacement effect appears to be limited, although temporary shifts in distribution have been reported (Stone *et al.* 1997; Culik *et al.* 2000; IWC 2000; Larsen and Hansen 2000; Anonymous 2002; Berggren *et al.* 2002; Carlström *et al.* 2002). However, the problem of habituation is considered to be of potentially serious concern (Dawson *et al.* 1998; IWC 2000; Cox *et al.* 2001; Cox *et al.* 2003). Among cetaceans, some experiments on captive and wild harbour porpoises indicate a rapid habituation to pinger sounds within days of initial exposure (Cox *et al.* 2001; Teilmann *et al.* 2006), although other experiments have shown no evidence of habituation (Kastelein *et al.* 2001; Lockyer *et al.* 2001). It is unknown whether, or how quickly, small cetaceans would habituate to the presence of pingers on gillnets in an active fishery, but there is a concern that this might reduce the pingers' utility as tools to prevent incidental catch. For this reason, significant amounts of research have been focused on the development of pingers that prevent or reduce habituation by randomizing their signal output (Goodson *et al.* 1997; Cox *et al.* 2001; Lockyer *et al.* 2001). These devices show considerable potential in preventing habituation and a concurrent projected increase in incidental catch rates. In addition, some newly developed types of pingers are designed to be "interactive", in the sense that they only produce sounds after detecting echolocation signals from small cetaceans (Poulsen 2004). Some interactive pingers now emit "exploratory signals" that are meant to entice the approaching porpoise to investigate using echolocation signals, which then activate the pinger (Poulsen 2004). This may significantly reduce the likelihood of habituation, while simultaneously extending the pingers' battery life and limiting total sound output into the environment (Lockyer *et al.* 2001). Of course, such pingers then become less useful in preventing incidental catch of species that do not echolocate but do respond to pinger sounds, such as seabirds (Melvin *et al.* 1999).

Aside from these effects, pingers have been considered as an additional source of acoustic pollution, potentially impacting other species in as yet unidentified ways (IWC 2000). Some fish, particularly clupeids, are capable of hearing the sounds produced by pingers, which may negatively affect catches of these species when using nets that are equipped with pingers, and may affect fine-scale harbour porpoise distribution (Mann *et al.* 1997; Richter 1998; Aitken *et al.* 2000). This mechanism may be partially responsible for reductions in incidental catch of small cetaceans in herring nets equipped with pingers, and this may lead to reluctance to deploy pingers in these fisheries (Kraus *et al.* 1997). Concerns have also been raised that other species, particularly pinnipeds, might come to associate the sounds produced by pingers with a source of food in the form of fish entangled in the net, potentially enhancing depredation and gear damage (the 'dinner bell effect'; Mate and Harvey 1987; Melvin *et al.* 1999; Bordino *et al.* 2002). For this reason, fishers may well be reluctant to deploy pingers in areas where pinnipeds are common. No information is available on the effects of the deployment of pingers on incidental catch of pinnipeds.

The widespread use of pingers in gillnet fisheries around the world faces several other practical obstacles. First, the increased electronic complexity of pingers has led to a price increase. Although the earliest models could be manufactured for less than US$10, the price of commercially available pingers currently runs between US$40 and US$80 per unit, making these devices an economically impractical solution in artisanal gillnet fisheries in many developing countries (Read 2000). In some jurisdictions such as Denmark, where the use of pingers has been made mandatory in several fisheries, the initial costs of obtaining pingers have been completely or partially met by government funding, but most additional costs of obtaining new pingers or replacing malfunctioning ones will have to be borne by fishers (Anonymous 2005).

The complexity of modern pingers enhances their capabilities but also makes them less robust and more susceptible to damage while being handled in conjunction with fishing gear. Fishers have reported that pingers may interfere with the deployment and retrieval of nets, and concerns have been raised over the potential effects of some pinger models on the underwater behaviour of the net due to changes in distribution of flotation devices (Read 2000; Larsen 2004). The increased complexity of pingers also means that fishers can no longer repair them themselves in case of a malfunction.

The battery life of pingers has been increased to months or even years by several technological advances (Lockyer *et al.* 2001). However, once the batteries run out, the pinger loses its function as a deterrent (Lockyer *et al.* 2001). Concerns have been raised over the potential for 'acoustic corridors', when a single pinger in a series along a string of nets fails, producing the appearance of a passageway between sound sources that may guide small cetaceans into acoustically silent portions of the net (IWC 2000). Most pinger models do not allow for battery replacement, and these devices are replaced (Lockyer *et al.* 2001). Some companies offer recycling programs for pingers but the effectiveness of such programs has not yet been evaluated. In many remote fishing communities, adequate recycling facilities for batteries may not be available, potentially leading to batteries or entire pingers being discarded.

Finally, regulations surrounding pinger usage have proven difficult to enforce. Even in jurisdictions where the use of pingers is mandatory, such as the

Gulf of Maine and the Danish North Sea gillnet fisheries, widespread lack of compliance has been reported (Read 2000; F. Larsen, DIFRES, pers. comm.). This is mainly due to a lack of enforcement capacity on the part of the relevant authorities. In most cases, marine enforcement agencies presently appear to be insufficiently equipped or willing to evaluate the presence of correctly functioning pingers on fishing gear. Instead, nets may be inspected on board or in port to assess the state of the pingers, but these methods are time-consuming and have other practical drawbacks that reduce efficiency. Any management programme that aims to reduce incidental catch of small cetaceans in gillnet fisheries by the widespread use of pingers must consider the practical limitations to the enforcement of these regulations to be successful. Formally giving fisheries observers the responsibility to monitor correct deployment of functional pingers could improve the efficacy of pingers as a conservation tool, but such observer programmes may not be available or practical in every case. This also further increases the workload of fisheries observers, who already have a significant number of tasks to perform.

While pingers aim to actively alert large marine vertebrates to the presence of gillnets, there have also been attempts to change the configuration of webbing or the physical structure of the net materials to enhance their overall detectability. This could mean improving the underwater visibility of nets, by using twine that is thicker, brightly coloured, or otherwise visually conspicuous.

The addition of highly visible mesh panels in the upper portions of gillnets has been proven to effectively reduce the incidental catch of alcid seabirds, without significantly affecting the catch of the target species (Melvin *et al.* 1999). However, these aides may be less useful in turbid waters or when fishing at night.

For small cetaceans, research has focused on means to enhance the acoustic qualities of gillnets, so that they might be more easily detected by the animals when echolocating. Several types of modifications have been attempted, often involving the inclusion of different types of line or other reflective material into the mesh of the net. Based on field experiments, the effectiveness of these measures has been considered to be generally limited, while in some cases reducing fish catches (Au and Jones 1991; Dawson 1994; Hatakeyama *et al.* 1994; IWC 2000). Gillnets made out of high-density monofilament line, using barium sulphate ($BaSO_4$) or iron oxide (Fe_2O_3) as filler inside the polymer, have been reported to catch fewer harbour porpoise than nets made of standard materials (Larsen *et al.* 2002; Trippel *et al.* 2003). Such nets might significantly reduce the incidental catch of small cetaceans. Potential benefits of this method would include the absence of habituation by porpoises to sound sources, the potential to function continuously without an external power source or mechanical and electronic components, and the absence of additional acoustic pollution of the surrounding marine environment. Nonetheless, there are still many uncertainties associated with the behaviour of such nets in actual fishing operations. There is only a limited understanding of the precise method by which small cetaceans appear to avoid entanglement in these nets. There is disagreement between the studies by Larsen *et al.* (2002a) and Trippel *et al.* (2003) in terms of whether or not the modified nets are significantly more acoustically reflective than the standard type of net, although this may partially depend on the materials used. Cox and Read (2004) and Larsen *et al.* (2002) suggested that harbour porpoises did not show increased echolocating activity around modified nets, despite what would be expected if the increased reflectivity of these materials led to detection of the nets through exploratory echolocation. Larsen *et al.* (2002) also reported a 30% reduction in catches and a reduction in average length of the target species (Atlantic cod) caught in the modified nets during field trials. These nets may have prevented entanglement of both harbour porpoise and large Atlantic cod due to their increased stiffness under water, rather than their enhanced acoustically reflective properties.

Clearly, more research is needed to evaluate the use of chemically-treated nets in actual fishing operations. It is possible that the properties of such nets may adversely affect their catch rates and handling efficiency, which would reduce the likelihood of acceptance of this technology by the industry. However, if the increased stiffness of the nets is the factor that reduces incidental catch of small cetaceans, it may be possible to develop a gillnet for commercial use that is stiffer than currently used nets (Cox and Read 2004). Such a net would have to be comparable in target species catch rate, while being stiff enough to avoid entanglement of small cetaceans (Read 2000). These nets could significantly reduce the incidental catch of small cetaceans worldwide. Development studies and field trials of such materials are urgently required in commercial fisheries around the world.

8.3.3 - Alternative Fishing Methodologies and Fishing Gears

In addition to changing the materials used in gillnets to improve their detectability, changes in the deployment of gillnets can also reduce incidental catch of large marine vertebrates. Possible aspects that could be managed include the number of nets, net length, mesh size and shape, deployment depth, soak time and time of day (Melvin *et al.* 1999; Read 2000; Gilman *et al.* 2005).

Reducing the number and length of nets can have a positive effect on incidental catch levels, but care must be taken that fishers do not compensate for this by increasing the soak time of each net. Changes in mesh sizes and shapes have long been used as a means to select the types of fish most likely to get entangled in gillnets, and considerable expertise is available with which to attempt incidental catch reductions (Alverson and Hughes 1996). Time of day during which nets are fishing can also have a substantial effect on the levels of incidental catch of some species that hunt at specific times of day, and most of these catches may be avoided by changing the deployment time of the gear (Melvin *et al.* 1999; see also below). Measures such as these are already in use as components of management strategies to reduce incidental catch of small cetaceans in fisheries in the United States (Read 2000).

Alternatively, there may be opportunities to induce fishers to use different gear types that may have a reduced impact on large marine vertebrates. This involves a detailed study of the reasons why fishers use a particular fishing strategy in a given area, and an analysis of the specific environmental and economic conditions under which they operate. For this reason, fishers should be involved in such programmes from the start. A possibility might be an increased use of hook and line fisheries that were common in many areas before the introduction of gillnets. Greater use of recently developed, commercially-available fish pots is another potential solution (Pol *et al.* 2005; Walsh and Hiscock 2005; Walsh *et al.* 2006). This gear type offers potential in reducing incidental catch of most non-target species such as small cetaceans to zero due to the configuration of the gear, which allows fish such as cod to enter a baited, cage-like structure, or pot, placed on the sea floor, where they remain alive until the pot is lifted. Fish pot technology is currently used in groundfish fisheries in several regions, such as the Gulf of Alaska, and attempts are being made to adapt this gear type to the specific requirements of fishers in Newfoundland and Labrador and the Gulf of Maine (Pol *et al.* 2005; Walsh and Hiscock 2005). If adopted, this gear may lead to significant reductions in incidental catch of small cetaceans, while at the same time generating a fresh product of increased value. However, the potential for entanglement of species such as baleen whales and marine turtles in ropes leading to the surface may be cause for concern, and should be further investigated. Some form of acoustic alerting device may help prevent incidental catch in these lines (Lien *et al.* 1992). Despite the advantages offered by fish pots, it may prove difficult to persuade fishers to refrain from using a gear type such as gillnets that has proven successful in the past (IWC 1994). Potentially, the use of gillnets could also be discouraged by placing an additional levy on fishing licenses using these nets. The levy could be based on the ratio of incidental catch to targeted catch. Such a system could discourage fishers from using gillnets in favour of other, less destructive methods.

Some fisheries occur over relatively short periods, targeting species with rapid migratory movements. The opening and closing dates of such fisheries may be set conservatively, to allow fishers ample time to catch their quota. However, it is possible to schedule fishing opening and closing dates based on the relative abundance of other species (e.g. seabirds), relative to the abundance of the target species, to prevent large amounts of fishing gear left in the water catching unwanted species while abundance of the target species is low (Melvin *et al.* 1999). This suggestion was also made by Lesage *et al.* (2004), who identified an increase in incidental catch of harbour porpoise, combined with a decrease in the landed catch of Atlantic cod, toward the end of the fishing season in the Gulf of St. Lawrence. Management of these fisheries may allow for more focused opening and closing dates than is currently the case, without substantially decreasing total catches of the target species.

8.3.4 - Fishing Effort Reductions

Typically, the primary objective of a drive towards reducing fishing effort is conservation of depleted fish stocks, which can be achieved through a variety of means. These include limits on the Total Allowable Catch for target species, restrictions in the duration of fishing seasons and/or reduction in the number of fishing vessels or licenses (FAO 2004). Such rationalisation methods are likely to be unpopular among the fishing industry, but may prevent collapses of fish stocks or allow depleted stocks to recover (FAO 2004). While these measures are in place, they can provide an important window of opportunity for depleted populations of large marine vertebrates to rebuild, but additional conservation measures to manage such populations will need to be considered if fisheries using the same gears that originally led to the depletion, such as bottom-set gillnets, are to be reopened (Read 2000).

8.3.5 - Incidental Catch Quotas

An alternative policy instrument to reduce incidental catches of large marine vertebrates might be to grant some form of incidental catch quota to fishers, where the fishery would be closed once a predetermined number of animals had been captured. A version of this system is currently operational in the international purse seine fishery for yellowfin tuna in the eastern tropical Pacific Ocean, where it has contributed to a significant reduction in the catches of various species of dolphins (Gosliner 1999; Hall *et al.* 2000; Lennert-Cody *et al.* 2004; see also Chapter 1). Under the current management regime, annual dolphin quotas are set for the whole industry. Individual vessels may request a non-transferable portion of this overall quota if they fish for tuna in a manner that would endanger dolphins. If the vessel reaches this quota limit, it is thereafter banned from fishing in this manner for the remainder of the fishing season, and has to switch to alternative methodologies. The 100% observer coverage requirement has undoubtedly been an important factor in ensuring adherence to these regulations.

The benefit of this system is that it directly encourages the individual vessel's adoption of fishing methodologies that minimise the catch of dolphins. Since this system was introduced, annual catches of dolphins dropped from approximately 19,500 in 1993 to below 3,000 by 2002. Although this level of mortality is generally considered to be biologically insignificant, stocks of dolphins have not recovered despite the reduction in mortality, for reasons that are currently unknown (Gerrodette and Forcada 1999; Gosliner 1999). An additional problem with this protocol would be that changes in fishing methodology brought about by this system may increase the incidental catches of other species, such as sharks, billfish and sea turtles (Lewison *et al.* 2004). Therefore it is imperative that effects of changes in management are better understood than is currently the case (Norris *et al.* 2002).

Individual Transferable Quotas (ITQs) typically refer to quotas of target fish species that are assigned by management agencies to individual fishers to catch at their convenience during the course of a single fishing season; they can also be sold (are transferable) between fishers (Copes 1986). They are commonly used in fishing industries around the world for a variety of target species (Arnason 1998; Dewees 1998). There have been calls to institute ITQs for catches of harbour porpoises in the New England gillnet fishery (Bisack and Sutinen 2006). However, more work needs to be done in order for large marine vertebrate ITQs to become an accepted component of incidental catch reduction strategies. A potential practical problem with this method includes the requirement for comprehensive observer coverage approaching 100%, to ensure compliance. This is not a problem in the yellowfin tuna purse seine fishery, but can be difficult to achieve in situations where the industry is widely dispersed and/or consists of many small vessels.

8.4 - Suggestions for Improvement in Newfoundland and Labrador Incidental Catch Management

8.4.1 - Improvement of Incidental Catch Data Collection Protocols

The quality of the incidental catch estimates presented here is only as good as the quality of the datasets on which the estimates are based. Unfortunately, these datasets, specifically the Bycatch Collector and Fishery Observer datasets, are incomplete, limited in scope, and contain highly variable data. The Bycatch Collector dataset contains data from a small number of fishers dispersed throughout the province, who were originally recruited to report on incidental catch of seals in their lumpfish nets. The focus of this programme has remained on the nearshore fisheries. Very few participating fishers are active in offshore fisheries such as those for monkfish, skates, white hake and Greenland halibut, despite the potential importance of these fisheries for incidental catch of small cetaceans and other large marine vertebrates. For more comprehensive monitoring of these fisheries, further targeted expansion of the number of Bycatch Collectors involved in these fisheries appears warranted.

The long-term relationship between individual fishers and DFO representatives is an essential part of the success of the Bycatch Collector programme, and should not be ignored if the data derived from this programme continues to be used for incidental catch monitoring purposes. Regular contact with fishers is essential to ensure continued quality of the dataset and improve accuracy of identification. This requires a willingness on the part of DFO to appropriate funds and resources to engage in this type of data collection.

The Fishery Observer programme provides highly variable incidental catch data. The reason for this variability lie in the essentially dualistic nature of the Fishery Observer programme in Newfoundland and Labrador, which attempts to collect data as a means of enforcement of fisheries regulations, as well as gathering scientific data. The two goals are at odds in several respects. The present programme is mainly focused on monitoring incidental catch of commercially valuable fish species, meaning that incidental catch of large marine vertebrates might be underreported. Observers are not deployed based on intensity of fishing effort or likelihood of encountering incidental catch, but rather based on the financial means available to the fishing sector in question to support them, as well as the capacity of fishing vessels to safely accommodate Observers. Due to cost-sharing arrangements of the Fishery Observer programme between the fishing industry and DFO, fisheries that experience low financial returns often lack funds to deploy observers. Safety concerns may prevent observers from monitoring catches from the smallest vessels, though these may experience high levels of incidental catch. Data collected by Observers are typically based on total weight of caught species, which is not useful when dealing with large marine vertebrates, where the approximate number of individuals is far more important. There is presently no mechanism to check Observer reports for errors. Since there is no independently verifiable record of incidental catch events other than the identification made by the Observer, there is no means to confirm the accuracy of the identification. This is a particular concern when several species that look similar occur sympatrically.

Several measures could improve data quality from the Fishery Observer programme. Observers need to be well-trained in identifying species of marine mammals, seabirds, and sharks. Equipping Fishery Observers with inexpensive digital cameras should be investigated. Observers could be required to photograph representative specimens of each species encountered as incidental catch for each haul. Provided that the Observers are instructed on which aspects of different species to photograph, such pictures would allow for subsequent validation of identifications and crosschecking of identification skills to assess potential retraining requirements. Observers should report the number of individuals, as well as the estimated total weight, of each species of large marine vertebrate that they record as incidental catch.

The Fishery Observer programme has, until now, been managed for DFO through SeaWatch Inc., a company based in St. John's. In 2006, DFO decided to open up the contracting arrangements for open bidding (J. Firth, DFO-NL, pers. comm). The intent was to allow companies to compete for contracts to encourage competition and reduce costs. Since then, concerns have been expressed over the possible effect of this policy change on Observer data quality. It is conceivable that companies may reduce the data that Observers collect to a bare minimum, unless regulations require them to collect additional information such as reports of incidental catch of large marine vertebrates. It is also unclear how concerns of overall profitability will influence the future distribution of Fishery Observers among different fishing sectors. It is unclear what the future role of the Fishery Observer programme is going to be, and whether it will become increasingly focused on collecting data for enforcement purposes, or if efforts will be made to ensure scientifically valid data collection protocols.

8.4.2 - Measures to Reduce Incidental Catch in Gillnet Fisheries

The Newfoundland fishing industry today has changed since the fisheries moratoria were put in place 14 years ago. There has been a significant reduction in the people employed in the fishery, and the main target species are currently crustaceans such as snow crab and northern shrimp (Schrank 2005). This has led to a reduction in the use of gillnets and codtraps in favour of crab pots and shrimp trawls that are thought to have less impact on small cetaceans, although sharks and bony fish are still likely to be affected. Nevertheless, entanglements of large marine vertebrates such as small cetaceans, seabirds and sharks still occur with some regularity in commercial gillnet fisheries. The nearshore fisheries for cod and lumpfish, and the offshore fishery for monkfish and skates, appeared to affect the widest range of species, although some species were primarily affected by other fisheries, such as deepwater sharks in the Greenland halibut fishery. Large confidence limits and a short data series preclude detailed analyses of trends in catch rates over the study period. Some reduction in incidental catch of large marine vertebrates has likely occurred in the years since the cod fisheries moratoria were put in place. However, redistribution of fishing effort into other fisheries such as those targeting lumpfish and monkfish may have partially negated such reductions, or led to catches of other species that previously were not impacted.

Because of their wide-ranging impacts, fisheries for cod, lumpfish and monkfish are obvious targets for a comprehensive approach to reduce incidental catch of large marine vertebrates. When developing an incidental catch reduction strategy, it is important to avoid a focus on one species, or group of species, to the exclusion of all others, since regimes that may reduce incidental catch of one species may not reduce catches of another. This represents a departure from the single-species approach that traditionally has dominated fisheries management (Sissenwine and Murawski 2004). The degree to which fisheries impact large marine vertebrates needs to be considered for the entire diversity of species that are incidentally caught in fisheries, before widespread mitigation measures aimed at a single species are introduced.

A measured approach to successfully reduce incidental catch of large marine vertebrates would make use of a variety of methods, some of which have been described previously. For example, research in the Bay of Fundy has suggested that harbour porpoises may follow herring schools in their daily vertical migration from deeper waters during the day to surface waters at night (Cox *et al.* 2001; Cox and Read 2004). Further studies on the preferred foraging depths of harbour porpoise in response to prey movements are clearly needed, but if fishers were to deploy bottom-set gillnets only at night, when porpoises might be foraging mainly near the surface, some reductions in incidental catch might be achieved. Similar changes to existing fishing practices may allow for substantial reductions in catches of seabirds and other species; for instance, alcids, which typically forage at dawn, may benefit from management regimes where nets are deployed during mid-day (Melvin *et al.* 1999). This is a good example of the importance of basic science to incidental impact reduction efforts within fisheries management.

Fishers should be encouraged to replace gillnets with fishing gear that is known to have a lesser impact on non-target species, although expansion of longline fisheries in particular should be monitored closely to ensure that this does not result in significant additional mortality of other species such as seabirds or marine turtles (Brothers *et al.* 1999; FAO 1999; Gilman *et al.* 2005). This might be achieved by introducing a levy on gillnets to discourage their use, as well as directed marketing schemes to promote the sale of fish that was not caught using gillnets among the general public, potentially for a higher price. Fish pots may provide an alternative fishing method that would eliminate incidental mortality of small cetaceans and sharks, while securing a fresh product of potentially higher market value, although the potential for entanglement of other species such as large whales or marine turtles should also be evaluated (Walsh and Hiscock 2005). In this way, the amounts of gillnets might be reduced without a reduction in landed catch, although introductions of new fishing gears must be monitored to ensure that they do not cause operational conflicts with established fishers using different gear types, as has been reported along the southwest coast of Newfoundland (P.Winger, MI-MUN, pers.comm.). In the same vein, large marine vertebrates (particularly pinnipeds) can be captured in various kinds of marine debris, including fishing gears that have been lost at sea but continue to fish, which is known as 'ghost fishing' (Kaiser *et al.* 1996; Laist 1996; Page *et al.* 2004; Boren *et al.* 2006). A recovery programme, similar to that conducted in other areas (e.g. Norway), will likely reduce the chance of animals becoming entangled in such nets (Anonymous, 1983–1999; Humborstad *et al.* 2003).

Chemically-treated nets may have significant potential as a means to reduce incidental catch of small cetaceans, provided the nets can be manufactured at relatively low cost and the catches of target species are not significantly affected. It is also possible that a combination of chemically-treated nets and pingers or other acoustic devices might produce satisfactory results (Culik and Koschinsky 2005). Pingers could also be made mandatory as a stand-alone measure in certain areas where high porpoise or seabird catches have been reported, possibly upon reaching a predetermined local incidental catch quota. Such areas could include the immediate vicinity of seabird colonies, where incidental catch of particularly alcids is high (Piatt and Nettleship 1987; Troke 2005).

Certain regions that are of significant importance to large marine vertebrates might have to be closed to gillnet fisheries, either as a time-area closure or on a more permanent basis. Areas that appear to be important to harbour porpoise, based on frequency of incidental catch and sighting reports, include St. Mary's Bay (in NAFO Unit 3Lq), the Carbonear islands (in NAFO Unit 3Lf), waters north of Fogo Island (in NAFO Unit 3Ki), and sections of the Strait of Belle Isle (NAFO unit 4Ra). Large concentrations ('rafts') of seabirds occur in offshore areas of the Grand Banks and Labrador shelf, as well as waters adjacent to the well-known breeding colonies (Brown *et al.* 1975). There is evidence that the southwestern Grand Banks are an important breeding habitat for porbeagle sharks (Campana *et al.* 2001). However, for many species the implementation of closures requires greater knowledge of what can be considered critical habitat. Until such data are available, a proactive approach should be employed.

In Canada, the federal Species At Risk Act (SARA) grants the minister of Fisheries and Oceans the power to administer Incidental Harm Permits (IHPs) to fishing enterprises, as part of their fishing licenses. These permits allow the incidental catch of a species that is listed under SARA to take place without resulting in legal action being taken against the fisher, under the condition that the species be released alive whenever possible. However, such permits are only granted after DFO conducts a scientific review on the impact of the fishing operations on the species for which the incidental take permit is being sought. The permit can only be granted if it is determined that the proposed level of incidental catch would not pose a threat to the survival or recovery of the species (D. Osborne, DFO-NL, pers. comm.). Since 2004, IHPs have been issued to fishers who are at greatest risk of accidentally capturing currently listed species (which include northern wolffish [*Anarhichas denticulatus* Krøyer], spotted wolffish [*Anarhichas minor* Olafsen] and leatherback sea turtles [*Dermochelys coriacea* L.]). This process has not yet been initiated for other large marine vertebrates such as harbour porpoise or porbeagle shark, but it is an additional management option once a final decision on the listing status of the Northwest Atlantic populations of harbour porpoise under SARA has been reached. Enforcement of these regulations is the responsibility of DFO Fisheries Officers.

Finally, incidental catch of large marine vertebrates is likely to be reduced as a result of an overall reduction in fishing effort, through measures such as the buying back of fishing licenses, reduction of subsidies for shipbuilding, and a vessel retirement policy (CEC 2002a). This particular management strategy is unlikely to be pursued as a conservation measure for small cetaceans in Newfoundland and Labrador, but may possibly be used as part of the ongoing long-term process to rationalize the fishing industry, leading to a reduction in incidental catches of small cetaceans as a beneficial side-effect.

For any attempt to reduce incidental catch of large marine vertebrates to work, a constructive long-term dialogue with representatives of the fishing industry is essential, as demonstrated in the United States' experience with marine mammal Take Reduction Teams, as mandated by the Marine Mammal Protection Act (NMFS 1998b; Read 2000; COSEWIC 2003). Such a management approach to tackle the problem of incidental catch of small cetaceans has been in place in the Bay of Fundy since 1995, where it appears to have facilitated acceptance of conservation-related management changes by the fishing industry (Anonymous 1995; Richter 1998; Hood 2001; COSEWIC 2003). It is acknowledged that such an inclusive approach requires initial coordination and continued cooperation between sections within the Department of Fisheries and Oceans, as well as between different ministerial departments and between the federal and provincial governments, and an inclusive approach to interested stakeholders. The absence of a Canadian equivalent to the US Marine Mammal Protection Act (other than SARA) may make this a difficult process to initiate, but it will be the one most likely to generate results in the long term. Encouraging results have been achieved in the context of the Eastern Scotian Shelf Integrated Management (ESSIM) programme, and it is hoped that such a management regime can also be put in place in Newfoundland and Labrador (Rutherford *et al.* 2005). In December 2006, the federal goverment tabled draft legislation to renew the Fisheries Act, which requires a precautionary approach to managing fish habitat (Anonymous 2006).

It is essential that any management plan provide a series of clearly-stated objectives that can be tested independently to determine whether the goals of the plan have been achieved within a specified timeframe. Conservation plans to reduce incidental catch of large marine vertebrates in Newfoundland and Labrador should require data collection on population structure, distribution, and movements of the populations in the area, including monitoring offshore waters; however, for several pelagic species this degree of detail may not be obtained easily. In the interim, further field tests of different incidental catch prevention methodologies are urgently required in close collaboration with the fishing industry, to determine which methods work best.

8.5 - *Global Prognosis and Potential Solutions*

The management of incidental catch of large marine vertebrates has become an important and visible component of fisheries management in numerous jurisdictions. However, various factors complicate successful management of these issues. Information on abundance, distribution, migratory pathways, other sources of mortality, and life history strategies, is often lacking for many non-target species. This information will be difficult to obtain without undertaking a substantial research programme dedicated to the task. Third, many sectors of the fishing industry are not at all or insufficiently monitored for incidental catch, and the impact of these fisheries remains unknown. This includes artisanal fisheries, but also illegal, unregulated or unreported (IUU) fishing effort by modern vessels, often in international waters (FAO 2002; High Seas Task Force 2006). Fourth, the highly migratory nature of many large marine vertebrates means that their distribution will likely overlap with a wide variety of fisheries across large areas of ocean. A comprehensive look at incidental catch rates in as many fisheries as possible is therefore required, to accurately assess the cumulative impacts of incidental catch throughout the species' range. This requires an international perspective, since studies of incidental catches within national waters are likely to provide only a partial indication of incidental catches (Lewison *et al.* 2004). Fifth, the capacity to enforce management decisions in both national and international waters is limited, due in part to inadequate resources and the absence of binding international agreements. In international waters, vessels are considered to be under the jurisdiction of the nation in which the vessel is registered. This has led many fishing vessels to be registered in nations that do not have the capacity or political will to ensure that these vessels fish in a responsible manner. Use of these so-called 'flags of convenience' are a major current problem in managing IUU fisheries for commercially targeted species, and likewise complicate attempts to address incidental catch of large marine vertebrates (Gianni and Simpson 2005; High Seas Task Force 2006).

An insidious problem in fisheries management is the prevalence of the 'shifting baseline syndrome', describing the concept of continued exploitation of an ecosystem causing a steadily decreasing baseline of abundance and diversity that successive generations mistakenly consider to represent the undisturbed biological state of that ecosystem (Pauly 1995; Jackson 2001). Many species of large marine vertebrates have been substantially reduced in numbers or rendered extinct due to overexploitation, incidental mortality, habitat degradation, or other ecosystem changes (Kenyon 1977; Montevecchi 1994; Anderson 1995; Alverson and Hughes 1996; D'Agrosa *et al.* 2000). It is often difficult to comprehend how diverse marine ecosystems were in comparison to the current situation, but historical and archaeological evidence has been used to demonstrate the significant depletion that has occurred over centuries in many areas (Jackson 2001; Jackson *et al.* 2001; Pitcher 2001). Modern marine ecosystems often have a long history of exploitation behind them and their present state should not be considered "natural" in the sense of "untouched or unspoilt".

Despite these difficulties, progress has been made in recent years to monitor, reduce, and prevent incidental catches of large marine vertebrates in many areas. This includes international agreements, improved monitoring of fishers at sea, increased observer coverage, adaptations to fishing gears and methods to reduce or prevent incidental catch, closures of important areas to some or all fishing activity, and reduction of fishing capacity (Hall and Mainprize 2004). Many incidental catch problems could be reduced by ensuring compliance with existing regulations through more effective enforcement and implementation and/or expansion of Fishery Observer programs. Independent observer programmes are part of a trend towards increased surveillance and extension of control over activities on the high seas (FAO 2002; Gianni and Simpson 2005; Kourti *et al.* 2005; High Seas Task Force 2006). Monitoring of fish stocks over a large scale using innovative remote-sensing survey techniques could also improve timely management of fish stocks, and reduce the amount of fishing gear capable of catching large marine vertebrates used at any given moment (Makris *et al.* 2003).

Many currently available methods to reduce incidental catch could be made available to fisheries in other parts of the world, particularly in developing economies. Care should be taken to assess the potential effects of such introductions on local environments and the long-term likelihood of these innovations being accepted, before widespread introduction. Further reductions could be achieved through innovative use of legislation, economic incentives and focused eco-labelling schemes (Gosliner 1999; Hall and Mainprize 2004), though there is a need to ensure that eco-labelling, in particular, is not misused (Brown 2005). There is a trend in fisheries management toward a management regime for large marine areas that incorporates all human activities impacting the marine ecosystem or parts thereof, including fisheries.

8.6 - Changes to Fisheries Management

Historically, fisheries management has focused on managing fish stocks on a single-species basis, with significant resources being directed toward stock assessment. Little consideration was given to the potential effects of fishing practices on other species, insofar as these did not have direct commercial value to other sectors of the fishing industry. In addition, a lack of scientific data on basic biological parameters of non-target species prevented an accurate assessment of the effects of incidental catch on these species (Anonymous 2005).

Rapid technological advances, often combined with generous financial incentives for increases in fishing vessel numbers, size and efficiency, have encouraged a significant expansion of fishing capacity, particularly since the declaration of the 200 nm Exclusive Economic Zones in 1977 (Hilborn *et al.* 2003; Schrank 2003; FAO 2004). Worldwide, the resulting overcapacity in fishing equipment has resulted in a great number of fish stocks being fished to commercial extinction (Pauly *et al.* 2003; FAO 2004; Anonymous 2005). These developments have resulted in a search for new management approaches that incorporate more components of the marine ecosystem (Weeks and Berkeley 2000). However, it must be recognized that historic failures in fisheries management have not, in themselves, been caused by the single-species management approach, but rather by the lack of political will to implement and enforce prudent management decisions (Mace 2004).

It is now acknowledged among the highest levels of government that the current state of affairs in the world's oceans is not only undesirable from a biological and economic point of view, but also may negatively impact significant portions of the world's population. Fish products are currently thought to provide approximately 2.6 billion people with at least 20% of their daily per capita intake of animal protein, and consumption of fish has increased substantially in many developing economies in recent years (FAO 2004). A more sustainable form of marine resource exploitation, in which the interrelationships between different components of the marine ecosystem are more fully taken into account, is therefore required. The Ecosystem Approach to Fisheries (EAF) implies the development of ecosystem-based fisheries management frameworks (e.g. NMFS 1998a; Caddy 1999; Garcia *et al.* 2003; Hall and Mainprize 2004). In effect, the global fishing industry is being asked to reduce its 'ecological footprint' to ensure its long-term survival (Folke *et al.* 1998).

The EAF has been endorsed at various high-level fora under the auspices of the United Nations (UN), such as the 1982 UN Convention on the Law of the Sea (UNCLOS 1982), the Food and Agriculture Organization's Code of Conduct for Responsible Fisheries (FAO 1995b), the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks (UN 1995), the Compliance Agreement (FAO 1995a) and the 2002 UN World Summit on Sustainable Development (UN 2002). It is understood that the ongoing global depletion of fish stocks contravenes the basic conservation requirements set out in these agreements (UNCLOS 1982; FAO 1995b; High Seas Task Force 2006). The UN Sustainable Development Summit's Plan of Implementation, therefore, calls on nations to "*...maintain or restore...*[fish]*...stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015*", and to "*...develop and facilitate the use of diverse approaches and tools, including the ecosystem approach, the elimination of destructive fishing practices, the establishment of* *marine protected areas consistent with international law and based on scientific information, including representative networks by 2012 and time/area closures for the protection of nursery grounds and periods, proper coastal land use and watershed planning and the integration of marine and coastal areas management into key sectors*" (UN 2002, Section 31a, 32c). The present challenge lies in successful implementation of these concepts to affect practical advances in local management (Sissenwine and Murawski 2004). Canada has committed itself to establishing an ecosystem approach in fisheries management by means of the Oceans Act (Government of Canada 1996; DFO 2002b, 2006).

An Ecosystem Approach to fisheries "recognizes explicitly the complexity of ecosystems and the interconnections among its component parts" (DFO, 2002). An EAF requires 1) an accurate description of the ecosystem and its constituent components, 2) an assessment of the overall state of the ecosystem relative to a standard set by society, and assessment of possible threats to the continued functioning of that ecosystem or its components, and 3) adaptive management strategies to maintain or improve ecosystem status and mitigate potential threats, so that all components of an ecosystem are maintained to ensure long-term persistence (Garcia *et al.* 2003; Lotze 2004). An EAF allows for the full costs and benefits of marine resource extraction to be taken into account (Sissenwine and Murawski 2004).

EAF is firmly based on the Precautionary Principle, which states that the absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures (FAO 1995b). This strategy is generally referred to as the Precautionary Approach, i.e., a management regime that errs on the side of caution when adequate information is not available (e.g. Government of Canada 1996; UN 2002). Reduction of incidental catches in fishing gear is but one aspect of such an approach in the marine context, which may also include the closure of certain areas to specific activities, reduction in fishing effort, tight controls on mineral resource extraction, shipping and acoustic pollution, and prudent watershed management on adjacent coasts (UN 2002). The introduction of some form of Marine Protected Areas (MPAs), where fishing or other anthropogenic activities are reduced or excluded, can also be a component of an EAF (Agardy 2000; Sumaila *et al.* 2000).

Related to such a management approach is the concept of Large Marine Ecosystems (LMEs), defined as "areas of ocean space encompassing coastal areas from river basins and estuaries out to the seaward boundary of continental shelves and the seaward margins of coastal current systems, and characterized by distinct bathymetry, hydrography, productivity, and trophically dependent populations" (Sherman 1992, 1995). This approach recognises the geographic extent of marine ecosystems and their frequent straddling of jurisdictional boundaries (Garcia *et al.* 2003). Large Ocean Management Areas (LOMAs) can be established to generate an integrated ocean management policy that also includes impacts on marine environments from terrestrial watersheds (Done and Reichelt 1998; DFO 2002; Foster *et al.* 2005; Rutherford *et al.* 2005). This concept can enhance an EAF by considering fisheries alongside other marine interests in a larger management context. Such a policy explicitly attempts to foster collaboration amongst resource users, stakeholders, the public, managers and politicians, to achieve comprehensive planning and long-term management of oceans and their associated marine resources (DFO 2002; Rutherford *et al.* 2005). However, LMEs may be complicated to define (Done and Reichelt 1998).

The management goals of an EAF should be clear and testable. There is also a requirement for a clear set of biological and environmental indicators to determine if the management goals are being met, and protocols for corrective action if warranted by indicators (Done and Reichelt 1998). Indicators could include the degree of ecological disturbance, species diversity, and number of endemic species. In addition, an organisational feedback system is required so that changes to the management plan can be quickly implemented when relevant information on the indicators becomes available. This will require a continued commitment of financial resources to the responsible management agencies.

Keeping in mind the pervasiveness of the 'shifting baseline syndrome', it may not be appropriate to restrict the goal of marine ecosystems management to merely maintaining the status quo. Rather, there is significant evidence that many marine ecosystems are severely depleted when compared to their pre-exploitation state (Pauly *et al.* 1998; Pitcher 2001; Myers and Worm 2003). The goal should therefore be to facilitate a recovery of marine ecosystems away from depleted states through a combination of strategies (Pitcher 2001). The potential for reintroductions of species in areas of their former range where they have been extirpated should also be considered (Pitcher 2001). Such an approach may appear unrealistic at present, given short-term incentives for rapid exploitation, but long-term restorative action has the potential to greatly increase the value of marine resources. Current discount rates favour present-day intensive exploitation of marine resources, and investing the profits, over efforts aimed at mitigation or future restoration (Sumaila 2004). However, a different intergenerational discounting model, which values benefits derived from conservation (e.g. fish protein) according to the discounting rates of the receiving future generations, instead of limiting itself to the present generation, allows for the explicit incorporation of future benefits into current marine resource management (Sumaila 2004; Ainsworth and Sumaila 2005).

In recent years, Canada has gained experience in developing management tools suited for putting an EAF into practice. The development of the Eastern Scotian Shelf Integrated Management project is particularly important, as it provides an opportunity to build experience in addressing divergent interests related to ocean management in Canada and elsewhere (Rutherford *et al.* 2005). In recent years, DFO has developed Integrated Fisheries Management Plans that attempt to incorporate the interactions between the fishery, other industries and the surrounding environment (DFO 2002a). These first steps are of vital importance for the implementation of an ecosystem-based management system under Canadian marine governance. The current process of renewing the Fisheries Act represents another part of this process (Anonymous 2006).

8.6.1 - Environmental Impact Studies of Fisheries' Effects on Marine Ecosystems

In many parts of the world, considerable time and resources are spent evaluating the potential environmental effects of anthropogenic impacts in nearshore and offshore waters. These include coastline development for industrial, commercial or residential purposes, garbage disposal at sea, military exercises, large-scale scientific research projects and the exploration and extraction of oil and natural gas. Development may not be allowed to proceed unless changes to the plan are implemented to reduce impact on the surrounding ecosystem. A system of regular monitoring ensures that impacts are minimised.

Consultations to determine the potential impacts of these activities on the biotic and abiotic components of the surrounding environment are both expected by the general public and mandated by legislation. It is inconsistent that the fishing industry should be exempt from such a review process, since several components of this industry arguably have a more significant destructive impact on marine environments than many other economic activities (Lemons 1998; Garcia *et al.* 2003). It is time to reconsider the scope of fisheries management and apply methods from other industry sectors to minimize negative fisheries impacts. In its 1995 Code of Conduct for Responsible Fisheries, the FAO implicitly recognised this by stating that " in the case of new developed or exploratory fisheries, States should adopt as soon as possible cautious conservation and management measures" until long-term fishery effects have been assessed (FAO 1995b). A more rigorous process is required, including a determination of the scale of the impact before activity is permitted, and subsequent monitoring of the impact to assess the degree of environmental damage, if present.

In the Canadian context, an impact assessment and monitoring strategy exists for other industries that affect marine habitats, such as habitat alteration or the discharge of effluents. Mandated through the Canadian Environmental Assessment Act, Evironmental Effects Monitoring (EEM) methodology allows for the testing of predictions on environmental impacts made through previously conducted Environmental Impact Studies (CEAA 2005). This is typically achieved through detailed monitoring of a series of abiotic and biotic factors in both affected and unaffected habitats that are compared to assess potential adverse effects. Such monitoring can continue over a series of years. EEM thus requires public scrutiny before undertaking an activity potentially detrimental to marine resources, continued monitoring of the activity once it occurs, and development of mitigation measures to reduce or prevent adverse effects.

In a fisheries context, modern fisheries management typically implements measures such as effort controls, fishing gear modifications and local closures to prevent overexploitation of commercially important fish stocks. Some negative effects of fisheries on non-target species can be incorporated into management plans (e.g. high levels of incidental catch of some threatened species such as Atlantic cod in other gillnet fisheries may lead to local fisheries closures), such effects are only dealt with once they are known to occur, on an *ad hoc* basis. There is presently little or no attempt by fisheries management agencies to predict the possible effects of introducing new fishing gears or methods into an existing fishery, or expanding a fishery into areas where it was previously absent. Given the wide geographic range and low levels of observer coverage in most fisheries, considerable damage can be done before problems become apparent and regulations need to be implemented to address the problem.

An Environmental Effects Monitoring approach to fisheries would require that the potential impact of major changes in fisheries management (e.g. increases in quotas, changes in fishing gears, changes to fishing seasons, areas) be assessed before widespread industry adoption, and that these assessments are binding and public. Relevant information could be collected by studying the long-term effects of similar fishing methodologies in other areas through detailed comparative surveying effort in impacted and relatively pristine areas. As well, small-scale experiments using controlled impacts could be performed, allowing the process of recovery from the impact to be predicted. In this way, the various possible effects of change in fisheries methodology could be assessed.

When changes to the intensity, methodologies or geographic range of fisheries are proposed, there should be a legislative requirement for an independent party to assess, among other impacts, the likelihood of incidental catches and their potential impact on the populations of the species involved, before the changes are implemented. Such monitoring could involve exploratory fisheries to determine the occurrence of incidental catch, and using available information on abundance, distribution and impacts of fisheries on the species of concern in other areas. If incidental catch rates are deemed likely to exceed previously set limits based on the life history, population size and growth rate of the species in question, additional conservation measures may be required before the change to the fishery can be implemented. This use of predetermined limits is similar to the Potential Biological Removal concept (PBR) used under the U.S. Marine Mammal Protection Act (Wade 1998). In effect, this places the burden of proof on the industry that stands to benefit from the change (in this case the fishing industry), as is standard with many other industries (Dayton 1998; Agardy 2000). Such a method is scientifically sound in the sense that it explicitly makes predictions about the impact of an event and then sets out to test the validity of these predictions. This method has not been used in a commercial fisheries context in Canada, but it is firmly rooted in the Fisheries Act, and could be used to evaluate the effects of fisheries management practices. Such a process would prevent potentially destructive fisheries management decisions by explicitly requiring prior consultation with outside experts and other stakeholders, including those not involved with the fishing industry.

Using the present study of incidental catch of small cetaceans and other large marine vertebrate species as an example, catch rates indicate that some species such as harbour porpoise are caught in substantial numbers under current fishing effort. Annual catch estimates of harbour porpoise are approximately 1,500 animals per year with large confidence limits. Most of these animals were caught in the nearshore cod gillnet fishery, despite widespread reduction in fishing effort for that fishery after the 1992 moratoria. Lack of reliable abundance estimates precludes a definitive assessment of the impact of this incidental catch. Based on this incidental catch estimate, several management options present themselves. All things being equal, it is to be expected that a further increase in cod gillnet fishing effort will lead to higher numbers of harbour porpoise being captured. Changing the opening dates from early to late summer in some areas will decrease the opportunities for harbour porpoises interacting with gillnets, while not substantially affecting target species catches. Reduction of gillnets in favour of handlines or "cod pots" would likely substantially reduce the incidental catch of this and many other large marine vertebrate species.

A first step in an EEM-style mitigation approach would be to identify the circumstances under which harbour porpoises get captured. These captures are still rare events, and a detailed assessment of circumstances surrounding these few cases could identify specific causes of these events. This could lead to recommendations impacting small numbers of fishers, or only applicable to spatio-temporally limited area, that might have a major impact on the incidental catch of harbour porpoises.

Given the potential for depletion through incidental catch, as witnessed in other parts of the species' range where large-scale gillnet fisheries exist, it can be hypothesized that the population of harbour porpoise in Newfoundland waters is under pressure from the present level of incidental mortality in gillnets. As such, any expansion of gillnet fisheries that are known to accidentally capture this species, such as the nearshore cod gillnet fishery, should not be allowed to go ahead without an assessment of the risks to populations of this and other species.

Some resistance to this new type of management is expected from both industry and within the Department of Fisheries and Oceans. A binding external analysis of impacts could reduce the flexibility by which the federal Minister of Fisheries and Oceans allocates fishing quotas. The federal government may also be required to review and possibly revise its position on the negative effects of different fishing gears. The proposed changes to the current Fisheries Act would address some of these issues (Anonymous 2006). Fishers might find their economic survival threatened if the Impact Assessment leads to restrictions on where, when and how they can fish. Assessments may take time to complete, meaning that managers may need to plan months or years in advance. Finally, there will be an additional cost to these assessments, and it is unclear who will ultimately bear them. This concept needs to be further developed before it can become a practical component of an EAF, but it has potential as a future management tool (Rieser 2005).

Using regular monitoring allows a variety of different impacts on living marine resources to be identified, and this knowledge needs to be shared among stakeholders and the public. The development of Integrated Ocean Management is essential to provide an open forum to address potential conflicts among resource users and other parties, based on the Precautionary Principle (Rutherford *et al.* 2005).

8.7 - Conclusions

Considerable numbers of different species of large marine vertebrates are captured annually in Newfoundland and Labrador's gillnet fisheries. Based on the analyses presented in previous chapters, the nearshore fisheries for cod and lumpfish and the offshore fishery for monkfish and skates appear to impact the widest variety of species, capturing several species in large numbers. It is suggested that efforts to address incidental catch of these species in gillnets should focus on these particular fisheries.

Incidental catch of large marine vertebrates is an important concern to ocean resource managers. Attempts to address this problem are being made, but there is a limit to what isolated projects can achieve. It is vital that such attempts be part of a comprehensive strategy to reduce the overall impact of society on the marine ecosystem. A good place to start is a re-evaluation of fisheries management strategies to incorporate potential risks of fisheries to non-target species. An impact assessment system similar to the one used by the Canadian Environmental Assessment Agency should be used to determine the potential effects of changes to fisheries management before these changes actually occur, and make binding recommendations to reduce or prevent the expected impacts. This could involve the mandatory use of mitigation techniques to alert non-target species to the presence of fishing gear.

Major problems facing fisheries management today include high mortality rates for both target and non-target species, often exceeding recommended levels; a significant overcapacity in the global fishing and fish processing sectors, leading to potentially unsustainable levels of exploitation and economic marginalisation; a lack of knowledge about the natural dynamics within pristine marine ecosystems, preventing recovery of depleted resources; and a lack of governance tools, public pressure, and political will to adopt a comprehensive precautionary management regime (Gréboval and Munro 1999; Mace 1997, 2004; NRC 1999). These problems are unlikely to be resolved with a piecemeal approach, but require a broad-based effort by all stakeholders. An Ecosystem Approach to fisheries, as part of a management structure for large marine ecosystems, appears a necessary approach to attempt to address the many and varied problems affecting marine ecosystems today.

Management measures are only useful for the protection and rebuilding of marine resources if the people and agencies involved (fishers, managers, politicians, conservation non-governmental organizations, the general public) promote their effectiveness. What is needed is the development of an Ocean

Ethic in all sectors of society, based on an understanding of the dependence of humans on the oceans for their well-being (Kellert 2005). Critical to this development is the realisation among broad levels in society that fishing is not a right, but a privilege, granted to fishers by society. This translates into stewardship of ocean resources and marine biodiversity within administrators, scientists, managers and those who exploit the ocean. The Code of Conduct for Responsible fisheries by FAO has an important role to play in fostering the development of such an Ocean Ethic among the fishing industry (FAO 1995).

There is also an important role for education to enhance knowledge of oceanic systems among the general public. In recent decades, significant changes have occurred in the attitudes displayed by society towards environmental degradation and conservation of endangered species and habitats (Kellert 2005). Marine systems, which often are less visible to many people, have yet to receive the degree of conservation afforded to many terrestrial ecosystems. On the other hand, marine systems, particularly those in deeper waters further offshore, were often left unexploited until comparatively recently, so they have not been impacted to the same extent as many terrestrial ecosystems (Mace 2004). The road to recovery of many components of these systems should be correspondingly shorter.

In conclusion, there is a current awareness of the need for further improvements in ecosystem-based management of the world's oceans. This concept is becoming widely established, and allows for dialogue between stakeholders where potential conflicts such as the incidental capture of large marine vertebrates in fisheries can be discussed before they become disruptive. This will require a change in management culture away from a narrow focus on the needs and requirements of the fishing industry. However, continued lack of political will and delays by management may undermine the effectiveness of these calls to action, and may lead to disengagement by the general public. Enough information currently exists to undertake decisive action toward management of the marine ecosystem and the various human effects on it, including incidental catch of large vertebrates. In order to circumvent these issues, it is paramount that these concerns are addressed in a comprehensive way by society at large.

8.8 - References

Agardy, T. 2000. Effects of fisheries on marine ecosystems: a conservationist's perspective. ICES Journal of Marine Science 57: 761-765.

Ainsworth, C.H. and U.R. Sumaila. 2005. Intergenerational valuation of fisheries resources can justify long-term conservation: a case study in Atlantic cod (*Gadus morhua*). Canadian Journal of Fisheries and Aquatic Sciences 62: 1104-1110.

Aitken, A., V.M. Peddemors and B. Allen. 2000. Fish reactions to pingers --can fishers afford to deploy pingers? 10th Southern African Marine Science Symposium (SAMSS 2000): Land, Sea and People in the New Millennium -- Abstracts.

Allison, G.W., J. Lubchenko and M.H. Carr. 1998. Marine reserves are necessary but not sufficient for marine coonservation. Ecological Applications 8 (1: Supplement): S79-S92.

Alverson, D.L. and S.E. Hughes. 1996. Bycatch: from emotion to effective natural resource management. Reviews in Fish Biology and Fisheries 6: 443-462.

Anderson, P.K. 1995. Competition, predation, and the evolution and extinction of Steller's sea cow, *Hydrodamalis gigas*. Marine Mammal Science 11: 391-394.

Anonymous, 1983–1999. Retrieval of lost fishing gears. Report Series 1983–1999. Available from the Library of the Directorate of Fisheries (in Norwegian).

Anonymous. 1995. Harbour porpoise conservation strategy for the Bay of Fundy. Halifax, NS, Department of Fisheries and Oceans (DFO), Resource Management Branch: 12 pp.

Anonymous. 2002. ASCOBANS recovery plan for Baltic harbour porpoises (Jastarnia Plan). Bonn, DE, Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas: 26 pp.

Anonymous. 2005. Revised Action Plan for the Protection of Harbour Porpoises. Kopenhagen, DK, Danish Joint Task Group on Marine Mammals: 47 pp.

Anonymous. 2005. Northern Cod: A failure of Canadian fisheries management. Report of the Standing Committee on Fisheries and Oceans, November 2005, Ottawa, ON, 60 pp. Available online at: http://www.parl.gc.ca/-committee/CommitteePublication.aspx?SourceId=137917.

Anonoymous. 2006. Canada's new government to modernize the Fisheries Act. DFO Press Release. Available online at: http://www.dfo-mpo.gc.ca/ media/newsrel/2006/hq-ac46_e.htm

Au, W.W.L. 1994. Sonar detection of gillnets by dolphins: Theoretical predictions. Report of the International Whaling Commission 15 (Special Issue): 565-571.

Au, W.W.L. and L. Jones. 1991. Acoustic reflectivity of nets: implications concerning incidental take of dolphins. Marine Mammal Science 7: 258-273.

Auster, P.J. and N.L. Shackell. 2000. Marine Protected Areas for the temperate and boreal northwest Atlantic: the potential for sustainable fisheries and conservation of biodiversity. Northeastern Naturalist 7 (4): 419-434.

Barlow, J. and G.A. Cameron. 2003. Field experiments show that acoustic pingers reduce marine mammal bycatch in the California drift gill net fishery. Marine Mammal Science 19 (2): 265-283.

Berggren, P., J. Carlström and N. Tregenza. 2002. Mitigation of small cetacean bycatch; evaluation of acoustic alarms (MISNET). Brussels, European Commission Directorate-General: 29 pp.

Boersma, P.D., and J.K. Parrish. 1999. Limiting abuse: marine protected areas, a limited solution. Ecological Economics 31: 287–304.

Bordino, P., S.D. Kraus, D. Albareda, A. Fazio, A. Palmerio, M. Mendez and S. Botta. 2002. Reducing incidental mortality of Franciscana dolphin *Pontoporia blainvillei* with acoustic warning devices attached to fishing nets. Marine Mammal Science 18 (4): 833-842.

Boren, L.J., M. Morrissey, C.G. Muller and N.J. Gemmell. 2006. Entanglement of New Zealand fur seals in man-made debris at Kaikoura, New Zealand. Marine Pollution Bulletin 52: 442-446.

Brothers, N.P., J. Cooper and S. Løkkeborg. 1999. The incidental catch of seabirds by longline fisheries: worldwide review and technical guidelines for mitigation. FAO Fisheries Circular 937, Rome, Italy: 100 pp.

Brown, J. 2005. An account of the dolphin-safe tuna issue in the UK. Marine Policy 29: 39-46.

Caddy, J.F. 1999. Fisheries management in the twenty-first century: will new paradigms apply? Reviews in Fish Biology and Fisheries 9 (1): 1-43.

Campana, S.E., L. Marks, W. Joyce and S. Harley. 2001. Analytical assessment of the porbeagle shark (*Lamna nasus*) population in the Northwest Atlantic, with estimates of long-term sustainable yield. Canadian Science Advisory Secretariat Research Document 2001/067. Dartmouth, NS, Canada, Department of Fisheries and Oceans.

Camphuysen, C.J., A.D. Fox, M.F. Leopold and I.K. Petersen. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. COWRIE Report BAM-02-2002: 39 pp.

Carlström, J., P. Berggren, F. Dinnetz and P. Börjesson. 2002. A field experiment using acoustic alarms (pingers) to reduce harbour porpoise by-catch in bottom-set gillnets. ICES Journal of Marine Science 59: 814-824.

CEAA [Canadian Environmental Assessment Agency]. 2006. Introduction to Environmental Assessment. Website accessed on June 15, 2006. Available online at: www.ceaa.gc.ca.

CEC [Commission of the European Communities]. 2002a. Communication from the Commission on the reform of the Common Fisheries Policy. Brussels, Belgium: 32 pp.

CEC [Commission of the European Communities]. 2002b. Incidental catch of small cetaceans. Report of the second meeting of the Subgroup on Fishery and Environment (SGFEN) of the Scientific, Technical and Economic Committee for Fisheries (STCEF). Brussels, B, Commission of the European Communities staff working paper SEC(2002) 1134: 63 pp.

CEC [Commission of the European Communities]. 2004. Council Regulation (EC) No 812/2004 of 26.4.2004 laying down measures concerning incdental catches of cetaceans in fisheries and amending Regulation (EC) No 88/98.

Copes, P. 1986. A critical review of the Individual Quota as a device in fisheries management. Land Economics 62 (3): 278-291.

COSEWIC. 2003. COSEWIC assessment and update status report on the harbour porpoise *Phocoena phocoena* (Northwest Atlantic population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON: vii + 30 pp.

Cox, T.M. and A.J. Read. 2004. Echolocation behavior of harbor porpoises *Phocoena phocoena* around chemically enhanced gill nets. Marine Ecology Progress Series 279: 275-282.

Cox, T.M., A.J. Read, D. Swanner, K. Urian and D. Waples. 2003. Behavioral responses of bottlenose dolphins, *Tursiops truncatus*, to gillnets and acoustic alarms. Biological Conservation 115: 203-212.

Cox, T.M., A.J. Read and N.J.C. Tregenza. 2001. Will harbour porpoises (*Phocoena phocoena*) habituate to pingers? Journal of Cetacean Research and Management 3 (1): 81-86.

Culik, B.M., S. Koschinski, N. Tregenza and G. Ellis. 2000. Reactions of harbour porpoises (*Phocoena phocoena*) and herring (*Clupea harengus*) to acoustic alarms. Marine Ecology Progress Series 211: 255-260.

Culik, B.M. and S. Koschinsky. 2005. Warning sounds at reflective nets: triggering and improving echolocation in harbour porpoises *Phocoena phocoena*. Document AC12/Doc.9(S) presented to the 12th ASCOBANS Advisory Committee Meeting, Brest, France, 12-14 April 2005: 25 pp.

D'Agrosa, C., C.E. Lennert-Cody and O. Vidal. 2000. Vaquita bycatch in Mexico's artisanal fisheries: driving a small population to extinction. Conservation Biology 14 (4): 1110-1119.

Dawson, S.M. 1994. The potential for reducing entanglement of dolphins and porpoises with acoustic modifications to gillnets. Reports of the International Whaling Commission 15 (Special Issue): 573-578.

Dawson, S.M., A. Read and E. Slooten. 1998. Pingers, porpoises and power: uncertainties with using pingers to reduce bycatch of small cetaceans. Biological Conservation 84 (2): 141-146.

Dayton, P.K., E. Sala, M.J. Tegner and S. Thrush. 2000. Marine reserves: Parks, baselines, and fishery enhancement. Bulletin of Marine Science 66 (3): 617-634.
DeMartini, E.E. and AM. Friedlander. 2004. Spatial patterns of endemism in shallow-water reef fish populations of the Northwestern Hawaiian Islands. Marine Ecology Progress Series 271: 281-296.
Deng, R., K. Dichmont, D. Milton, M. Haywood, D. Vance, N. Hall and D. Die. 2005. Can vessel monitoring system data also be used to study trawl intensity and population depletion? The example of Australia's northern prawn fishery. Canadian Journal of Fisheries and Aquatic Sciences 62 (3): 611-622.
DFO [Department of Fisheries and Oceans]. 2002a. Canadian Atlantic pelagic shark integrated fisheries management plan 2002-2007, Department of Fisheries and Oceans: 50 pp.
DFO [Department of Fisheries and Oceans]. 2002b. Canada's ocean strategy. Policy and operational framework for integrated management of estuarine, coastal and marine environments in Canada. Fisheries and Oceans Canada, 36 pp.
Done, T.J. and R.E. Reichelt. 1998. integrated coastal zone and fisheries ecosystem management: Generic goals and performance indices. Ecological Applications 8 (1: Supplement): S110-S118.
Drouin, M. 2001. Vessel Monitoring Systems gain ground. Pacific Fishing 22(6): 31.
FAO [Food and Agriculture Organisation of the United Nations]. 1995a. Agreement to promote compliance with international conservation and management measures by fishing vessels on the high seas. 10 pp. Available online at: http://www.fao.org/DOCREP/MEETING/-003/X3130m/X3130E00.HTM#Top%20Of%20Page.
FAO [Food and Agriculture Organisation of the United Nations]. 1995b. Code of conduct for responsible fisheries. FAO Fisheries Technical Paper, 47 pp. Available online at: www.fao.org.
FAO [Food and Agriculture Organisation of the United Nations]. 1999. International Plan of Action for reducing incidental catch of seabirds in longline fisheries. Rome, Italy: 10 pp.
FAO [Food and Agriculture Organisation of the United Nations]. 2002. Stopping illegal, unreported and unregulated fishing. Rome, Italy: 25 pp.
FAO [Food and Agriculture Organisation of the United Nations]. 2004. The State of World Fisheries and Aquaculture (SOFIA) 2004. 153 pp. Available online at: http://www.fao.org/sof/sofia/index_en.htm.
Folke, C., N. Kautsky, H. Berg, A. Jansson and M. Troell. 1998. The ecological footprint concept for sustainable seafood production: A review. Ecological Applications 8 (1: Supplement): 63-71.
Foster, E., M. Haward and S. Coffen-Smout. 2005. Implementing integrated oceans management: Australia's south east regional marine plan

(SERMP) and Canada's eastern Scotian shelf integrated management (ESSIM) initiaitve. Marine Policy 29: 391-405.
Garcia, S.M., A. Zerbi, C. Aliaume, T. Do Chi and G. Lasserre. 2003. The ecosystem approach to fisheries: issues, terminology, principles, institutional foundations, implementation and outlook. FAO Fisheries Technical Paper No. 443: 71 pp.
Garcia-Charton, J.A., I.D. Williams, A. Perez_Ruzafa, M. Milazzo, R. Chemello, C. Marcos, M.-S. Kitsos, A. Koukouras and S. Riggio. 2000. Evaluating the ecological effects of Mediterranean marine protected areas: habitat, scale and the natural variability of ecosystems. Environmental Conservation 27 (2): 159-178.
Gearin, P.J., M.E. Gosho, J.L. Laake, L. Cooke, R.L. DeLong and K.M. Hughes. 1996. Experimental testing of acoustic alarms (pingers) to reduce bycatch of harbour porpoise, *Phocoena phocoena*, in the state of Washington. Journal of Cetacean Research and Management 2 (1): 1-9.
Gell, F.R and C.M. Roberts. 2003. Benefits beyond boundaries: the fishery effects of marine reserves. Trends in Ecology and Evolution 18: 448–455.
Gerrodette, T. and J. Forcada. 1999. Non-recovery of two spotted and spinner dolphin populations in the eastern tropical Pacific ocean. Marine Ecology Progress Series 291: 1-21.
Gianni, M. and W. Simpson. 2005. The changing nature of high seas fishing: How flags of convenience provide cover for illegal, unreported and unregulated fishing, A report commissioned by the Australian Department of Agriculture, Fisheries and Forestry, International Transport Workers' Federation, and WWF International: 83.
Gilman, E., N. Brothers and D.R. Kobayashi. 2005. Principles and approaches to abate seabird by-catch in longline fisheries. Fish and Fisheries 6: 35-49.
González, R., C. Gaspar, L. Curtolo, I. Sanguiliano, P. Osovnikar and N. Borsetta. 2004. Fishery and oceanographic monitoring system (FOMS): A new technological tool based on remote sensing, with application in ecosystem management of coastal fisheries in Patagonia. Gayana (Concepción) 68 (2): 234-238.
Goodson, A.D., D. Newborough and B. Woodward. 1997. Set gillnet acoustic deterrents for harbour porpoises, *Phocoena phocoena*: improving the technology. ICES Council Meeting Paper 1997/Q:16: 5.
Gosliner, M.L. 1999. The Tuna-Dolphin Controversy. Pages 120-155 in J.R. Twiss Jr. and R.R. Reeves (eds.): Conservation and management of marine mammals. Smithsonian Institution Press, Washington, D.C., USA.
Government of Canada. 1996. The Oceans Act, 1996, c. 31: An Act respecting the oceans of Canada. Available on-line at http://laws.justice.gc.ca/en/O-2.4/89238.html.
Gréboval, D. and G.Munro. 1999. Overcapitalization and excess capacity in world fisheries: Underlying economics and methods of control. Managing

fishing capacity. Selected papers on underlying concepts and issues. FAO Fisheries Technical Paper no. 386, pp. 1-48.
Hall, M.A., D.L. Alverson and K.I. Metuzals. 2000. By-Catch: Problems and Solutions. Marine Pollution Bulletin 41 (1-6): 204-219.
Hall, S.J. and B. Mainprize. 2004. Towards ecosystem-based fisheries management. Fish and Fisheries 5 (1): 1-20.
Hatakeyama, Y., K. Ishii, T. Akamatsu, H. Soeda, T. Shimamura and T. Kojima. 1994. A review of studies on attempts to reduce the entanglement of the Dall's porpoise, *Phocoenoides dalli*, in the Japanese salmon gillnet fishery. Report of the International Whaling Commission 15 (Special Issue): 549-563.
High Seas Task Force. 2006. Closing the net: Stopping illegal fishing on the high seas. Final report of the Ministerially-led Task Force on IUU Fishing on the High Seas, Governments of Australia, Canada, Chile, Namibia, New Zealand, and the United Kingdom, WWF, IUCN and the Earth Island Institute at Columbia University: 116 pp.
Hilborn, R., T.A. Branch, B. Ernst, A. Magnusson, C.V. Minte-Vera, M.D. Scheuerell and J.L. Valero. 2003. State of the world's fisheries. Annual Review of Environment and Resources 28: 359-399.
Hood, C.C. 2001. Incidental capture of harbour porpoise, *Phocoena phocoena*, in three gillnet fisheries of the northwest Atlantic: investigation of possible causes. Ph.D. thesis, Biopsychology Programme, Memorial University of Newfoundland, St. John's, NL, Canada: 375 pp.
Hooker, S.K., H. Whitehead and S. Gowans. 1999. Marine protected area design and the spatial and temporal distribution of cetaceans in a submarine canyon. Conservation Biology 13 (3): 592-602.
Hoyt, E. 2005. Marine Protected Areas for whales, dolphins and porpoises. A World Handbook for Cetacean Habitat Conservation. Earthscan, London, UK.
Hughey, K.F.D. 2000. An evaluation of a management saga: The Banks Peninsula Marine Mammal Sanctuary, New Zealand. Journal of Environmental Management 58: 179-197.
Humborstad, O.-B., S. Løkkeborg, N.-R. Hareide and D.M. Furevik. 2003. Catches of Greenland halibut (*Reinhardtius hippoglossoides*) in deepwater ghost-fishing gillnets on the Norwegian continental slope. Fisheries Research 64: 163-170.
Hyrenbach, K.D., K.A. Forney and P.K. Dayton. 2000. Marine Protected Areas and Ocean Basin Management. Aquatic Conservation: Marine and Freshwater Ecosystems 10: 437-458.
Hyrenbach, K.D., C. Keiper, S.G. Dallen, D.G. Ainley and D.J. Anderson. 2006. Use of marine sanctuaries by far-ranging predators: commuting flights to the California Current System by breeding Hawaiian albatrosses. Fisheries Oceanography 15(2): 95-103.

IUCN [International Union for the Conservation of Nature]. 1999. Guidelines for Marine Protected Areas. World Commission on Protected Areas Best Practice Protected Area Guidelines Series No. 3, 127 pp.
IWC [International Whaling Commission]. 1994. Report of the Workshop on Mortality of Cetaceans in Passive Fishing Nets and Traps. Reports of the International Whaling Commission 15 (Special Issue): 6-57.
IWC [International Whaling Commission]. 2000. Annex 1: Report of the Sub-Committee on Small Cetaceans. Journal of Cetacean Research and Management 2 (Supplement): 235-263.
Jackson, J.B.C. 2001. What was natural in the coastal oceans? Proceedings of the National Academy of Sciences 98 (10): 5411-5418.
Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner and R.R. Warner. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293 (5530): 629-638.
Jamieson, G.S. and C.O. Levings. 2001. Marine protected areas in Canada - Implications for both conservation and fisheries management. Canadian Journal of Fisheries and Aquatic Sciences 58 (1): 138-156.
Kaiser, M.J., B. Bullimore, P. Newman, K. Lock and S. Gilbert. 1996. Catches in 'ghost fishing' set nets. Marine Ecology Progress Series 145 (1-3): 11-16.
Kastelein, R.A., D. de Haan, N. Vaughan, C. Staal and N.M. Schooneman. 2001. The influence of three acoustic alarms on the behaviour of harbour porpoises (*Phocoena phocoena*) in a floating pen. Marine Environmental Research 52 (4): 351-371.
Kastelein, R.A., A.D. Goodson, J. Lien and D. de Haan (1995). The effects of acoustic alarms on harbour porpoise (*Phocoena phocoena*) behaviour. Pages 157-168 in P.E. Nachtigall, J. Lien, W.W.L. Au and A.J. Read. (eds.): Harbour porpoises: Laboratory studies to reduce bycatch. De Spil Publications, Woerden, The Netherlands.
Kellert, S.R. 2005. Perspectives on an ethic toward the sea. American Fisheries Society Symposium 41: 703-711.
Kenyon, K.W. 1977. Caribbean monk seal extinct. Journal of Mammalogy 58: 97-98.
Kiraly, S.J., J.A. Moore and R.H. Jasinski. 2003. Deepwater and other sharks of the U.S. Atlantic Ocean Exclusive Economic Zone. Marine Fisheries Review 65 (4): 1-63.
Kourti, N., I. Shepherd, H. Greidanus, M. Alvarez, E. Aresu, T. Bauna, J. Chesworth, G. Lemoine and G. Schwartz. 2005. Integrating remote sensing in fisheries control. Fisheries Management and Ecology 12: 295-307.

Kraus, S.D., A.J. Read, A. Solow, K. Baldwin, T. Spradlin, E. Anderson and J. Williamson. 1997. Acoustic alarms reduce porpoise mortality. Nature 388 (6642): 525.

Laist, D.W. 1996. Marine debiris entanglement and ghost fishing: a cryptic and significant type of bycatch? Alaska Sea Grant Program Report AK-SG-96-03, pp.33-40.

Larsen, F. 2004. A note on improving the mechanism of pinger attachment for the Danish North Sea gillnet fishery. Journal of Cetacean Research and Management 6 (2): 147-150.

Larsen, F., O.R. Eigaard and J. Tougaard. 2002. Reduction of harbour porpoise by-catch in the North Sea by high-density gillnets. IWC Scientific Committee Working Paper SC/54/SM30, International Whaling Commission, Cambridge, UK: 12 pp.

Larsen, F. and J.R. Hansen. 2000. On the potential effects of widespread use of pingers in the North Sea. Paper SC/52/SM28 presented to the International Whaling Commission Scientific Committee Meeting, Adelaide, AU, June 2000 (unpublished).

Larsen, F., M. Vinther and C. Krog. 2002. Use of pingers in the Danish North Sea wreck net fishery. IWC Scientific Committee Working Paper SC/54/SM32, International Whaling Commission Cambridge, UK: 8 pp.

Lauck, T., C.W. Clark, M. Mangel and G.R. Munro. 1998. Implementing the precautionary principle in fisheries management through marine reserves. Ecological Applications 8 (1: Supplement): S72-S78.

Lemons, J. 1998. Burden of proof requirements and environmental sustainability: Science, public policy and ethics. Pages 75-103 in J. Lemons, L. Westra, and R. Goodland (eds): Ecological Sustainability and Integrity: Concepts and approaches. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Lennert-Cody, C.E., M. Minami and M.A. Hall. 2004. Incidental mortality of dolphins in the eastern Pacific Ocean purse-seine fishery: correlates and their spatial association. Journal of Cetacean Research and Management 6 (2): 151-163.

Lesage, V., J. Keays, S. Turgeon and S. Hurtubise. 2004. Incidental catches of harbour porpoises (*Phocoena phocoena*) in the gillnet fishery of the Estuary and Gulf of St. Lawrence in 2000-2002. Canadian Technical Report of Fisheries and Aquatic Sciences 2552: 37 pp.

Lewison, R.L., L.B. Crowder, A.J. Read and S.A. Freeman. 2004. Understanding impacts of fisheries bycatch on marine megafauna. Trends in Ecology and Evolution 19 (11): 598-604.

Lien, J., W. Barney, S. Todd, R. Seton and J. Guzzwell. 1992. Effects of adding sounds to cod traps on the probability of collisions by humpback whales. Pages 701-708 in J.A. Thomas, R.A. Kastelein and A.Y. Supin (eds.) Marine Mammal Sensory Systems. Plenum Press, New York, NY, USA.

Lien, J., C. Hood, D. Pittman, P. Ruel, D. Borggaard, C. Chisholm, L. Wiesner, T. Mahon and D. Mitchell (1995). Field tests of acoustic devices on groundfish gillnets: assessment of effectiveness in reducing harbour porpoise by-catch. Pages 349-364 in R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (eds.): Sensory systems of aquatic mammals. De Spil Publications, Woerden, The Netherlands.

Lien, J., D. Pittman, C. Hood, C. Richter, D. Borggaard, F. Marques and S. Todd. 1995. Entrapments in fishing gear and strandings in Newfoundland and Labrador reported to the Entrapment Assistance Programme during 1994. A report to the Department of Fisheries and Oceans and the Atlantic Fisheries Adjustment Programme, Memorial University of Newfoundland, St. John's, NL, Canada: 27 pp.

Lockyer, C., G. Desportes, M. Amundin and D. Goodson. 2001. The tail of EPIC - Elimination of harbour Porpoise Incidental Catch., Final Report to the European Commission of Project No DG XIV 97/00006: 249.

Lotze, H.K. 2004. Repetitive history of resource depletion and mismanagement: the need for a shift in perspective. In: Browman, H. I. and Stergiou, K. I. (eds) Perspectives on ecosystem-based approaches to the management of marine resources. Marine Ecology Progress Series 274: 282-285.

Mace, P.M. (1997). Developing and sustaining world fisheries resources: The state of the science and management. Proceedings of the 2d World Fisheries Congress, Brisbane, Australia, 28 Jul-2 Aug 1996: pp. 1-20.

Mace, P.M. 2004. In defence of fisheries scientists, single-sepcies models and other scapegoats: confronting the real problem. In: Browman, H. I. and Stergiou, K. I. (eds) Perspectives on ecosystem-based approaches to the management of marine resources. Marine Ecology Progress Series 274: 285-291.

Makris, N.C., P. Ratilal, D.T. Symonds, S. Jagannathan, S. Lee and R.W. Nero. 2003. Fish population and behavior revealed by instantaneous continental shelf–scale imaging. Science 311: 660-663.

Mann, D.A., Z. Lu and A.N. Popper. 1997. A clupeid fish can detect ultrasound. Nature (London) 389: 341.

Mate, B.R. and J.T. Harvey. 1987. Acoustical deterrents in marine mammal conflicts with fisheries, Newport, Oregon. Oregon State University, Sea Grant College Programme, Corvallis, OR.

McClanahan, T.R. and N.A.J. Graham. 2005. Recovery trajectories of coral reef fish assemblages within Kenyan marine protected areas. Marine Ecology Progress Series 294: 241-248.

Melvin, E.F., J.K. Parrish and L.L. Conquest. 1999. Novel tools to reduce seabird bycatch in coastal gillnet fisheries. Conservation Biology 13 (6): 1386-1397.

Melvin, E.F. and J.K. Parrish (eds.). 2001. Seabird Bycatch: Trends, Roadblocks and Solutions. University of Alaska Sea Grant, AK-SG-01-01, Fairbanks.

Mikol B. 1997. Temperature directed fishing: how to reduce bycatch and increase productivity. Marine Advisory Bulletin No. 48, Alaska Seagrant College Programme, University of Alaska, Fairbanks, AK, USA.

Molenaar, E.J., and M. Tsamenyi. 2000. Satellite-based vessel monitoring systems. International legal aspects and developments in state practice. FAO Legal Papers # 7: 45 pp.

Montevecchi, B. 1994. The great auk cemetery. Natural History 103: 6-8.

Murawski, S.A., R. Brown, H.L. Lai, P.L. Rago and L. Hendrickson. 2000. Large-scale closed areas as a fishery-management tool in temperare marine systems: The Georges Bank experience. Bulletin of Marine Science 66 (3): 775-798.

Murawski, S.A., P. Rago and M. Fogarty. 2004. Spillover effects from temperate marine protected areas. American Fisheries Society Symposium, 42: 167-184.

Murawski, S.A., S.E. Wigley, M.J. Fogarty, P.J. Rago and D.G. Mountain. 2005. Effort distribution and catch patterns adjacent to temperate MPAs. ICES Journal of Marine Science 62: 1150-1167.

Murray, K.T., A.J. Read and A.R. Solow. 2000. The use of time/area closures to reduce bycatches of harbour porpoises: Lessons from the Gulf of Maine sink gillnet fishery. (*Phocoena phocoena*). The Journal of Cetacean Research and Management 2 (2): 135-141.

NMFS [National Marine Fisheries Service]. 1998a. Ecosystem-based fishery management. A Report to Congress by the Ecosystem Principles Advisory Panel As mandated by the Sustainable Fisheries Act amendments to the Magnuson-Stevens Fishery Conservation and Management Act 1996. National Marine Fisheries Service, 54 pp.

NMFS [National Marine Fisheries Service]. 1998b. Taking of Marine Mammals Incidental to Commercial Fishing Operations: Harbor Porpoise Take Reduction Plan Regulations 50 CFR Part 229. Federal Register 63 (231): 27 pp.

NRC [National Research Council]. 1999. Sustaining marine fisheries. National Academy Press, Washington D.C., USA: 164 pp.

Norris, S., M.A. Hall, E. Melvin and J. Parrish. 2002. Thinking like an ocean: ecological lessons from marine bycatch. Conservation in Practice 3 (4): 10-19.

Page, B., J. McKenzie, R. McIntosh, A. Baylis, A. Morrissey, N. Calvert, T. Haase, M. Berris, D. Dowie, P.D. Shaughnessy and S.D. Goldsworthy. 2004. Entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris before and after Government and industry attempts to reduce the problem. Marine Pollution Bulletin 49: 33-42.

Palka, D. 2006. Summer abundance estimates of cetaceans in US North Atlantic Navy Operating Areas. Northeast Fisheries Science Center Reference Document 06-03: 48 pp.

Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10: 430.

Pauly, D., J. Alder, E. Bennett, V. Christensen, P. Tyedmers and R. Watson. 2003. The future for fisheries. Science 203: 1359-1361.

Pitcher, T.J. 2001. Fisheries managed to rebuild ecosystems? Reconstructing the past to salvage the future. Ecological Applications 11 (2): 601-617.

Pitcher, T.J., R. Watson, N. Haggan, S. Guénette, R. Kennish, U.R. Sumaila, D. Cook, K. Wilson and A. Leung. 2000. Marine reserves and the restoration of fisheries and marine ecosystems in the South China Sea. Bulletin of Marine Science 66 (3): 543-566.

Pol, M., P.S. Walsh and R. Marcella. 2005. Cod potting in Massachusetts: A demonstration project. Centre for Sustainable Aquatic Resources, Fisheries & Marine Institute of Memorial University of Newfoundland, Report P-153: 30 pp.

Poulsen, L.R. 2004. The efficiency of an interactive pinger (activated by biosonar) in displacing wild harbour porpoises, *Phocoena phocoena*, University of Aarhus, Denmark: 43 pp.

Read, A.J. 2000. Potential mitigation measures for reducing the by-catches of small cetaceans in ASCOBANS waters, Report to ASCOBANS: 22 pp.

Reeves, R.R. 2000. The value of sanctuaries, parks and reserves (protected areas) as tools for conserving marine mammals. Final Report to the Marine Mammal Commission, contract number T74465385. Bethesday, MD, USA, Marine Mammal Commission: 50 pp.

Richter, C. 1998. Harbour porpoise and people: Strategies for bycatch reduction in ther Bay of Fundy. Biopsychology Programme, Memorial University of Newfoundland, St. John's, NL, Canada: x + 150 pp.

Rieser, A. 2005. The legal requirement to address fishing effects on essential fish habitat: Thresholds, qualifiers, and the burden of proof. American Fisheries Society Symposium 41: 765-766.

Roberts, C.M., J.A. Bohnsack, F. Gell, J.P. Hawkins and R. Goodridge. 2001. Effects of marine reserves on adjacent fisheries. Science 294 (5548): 1920-1923.

Russ, G.R. and A.C. Alcala. 2004. Marine reserves: long-term protection is required for full recovery of predatory fish populations. Oecologia (Berlin) 138 (4): 622-627.

Rutherford, R.J., G.J. Herbert and S.S. Coffen-Smout. 2005. Integrated ocean management and the collaborative planning process: the Eastern Scotian Shelf Integrated Management (ESSIM) Initiative. Marine Policy 29: 75-83.

Schrank, W.E. 2003. Introducing fisheries subsidies. FAO Fisheries Technical Paper 437, 64 pp. Available online at: ftp://ftp.fao.org/docrep/fao/-006/y4647e/Y4647e00.pdf.

Schrank, W.E. 2005. The Newfoundland fishery: ten years after the moratorium. Marine Policy 29: 407-420.

Sherman, K. 1995. Achieving regional cooperation in the management of marine ecosystems: the use of the large marine ecosystem approach. Ocean & Coastal Management 29 (1-3): 165-185.

Sherman, K. 1992. Productivity, perturbations and options for biomass yields in large marine ecosystems. Pages 206–219 in K. Sherman, L.M. Alexander, and B.D. Gold (eds.): Large Marine Ecosystems: Patterns, Processes and Yields. AAAS Press, Washington, D.C., USA.

Simpfendorfer, C.A., K.Donohue, and N.G. Hall. 2000. Stock assessment and risk analysis for the whiskery shark (*Furgaleus macki* (Whitley)) in south-western Australia. Fisheries Research 47(1): 1-17.

Sissenwine, M. and S.A. Murawski. 2004. Moving beyond 'intelligent tinkering'; advancing an Ecosystem Approach to fisheries. Marine Ecology Progress Series 274: 291-295.

Stone, G., S. Kraus, A. Hutt, S. Martin, A. Yoshinaga and L. Joy. 1997. Reducing by-catch: can acoustic pingers keep Hector's dolphins out of fishing nets? Marine Technology Society Journal 31: 3-7.

Sumaila, U.R. 2004. Intergenerational cost-benefit analysis and marine ecosystem restoration. Fish and Fisheries 5: 329-343.

Sumaila, U.R., S. Guénette, J. Alder and R. Chuenpagdee. 2000. Addressing ecosystem effects of fishing using marine protected areas. ICES Journal of Marine Science 57: 752-760.

Teilmann, J., J. Tougaard, L.A. Miller, T. Kirketerp, K. Hansen and S. Brando. 2006. Reactions of captive harbour porpoises (*Phocoena phocoena*) to pinger-like sounds. Marine Mammal Science 22 (2): 240-260.

Tissot, B.N., W.F. Walsh and L.E. Hallacher. 2004. Evaluating effectiveness of a Marine Protected Area Network in West Hawai'i to increase productivity of an aquarium fishery. Pacific Science 58 (2): 175-188.

Trippel, E.A., N.L. Holy, D.L. Palka, T.D. Shepherd, G.D. Melvin and J.M. Terhune. 2003. Nylon barium sulphate gillnet reduces porpoise and seabird mortality. Marine Mammal Science 19: 240-243.

Trippel, E.A., M.B. Strong, C. Hood, C. Richter and J. Lien. 1996. By-catch of harbour porpoise (*Phocoena phocoena*) in the Lower Bay of Fundy gillnet fishery in 1995. St. John's, Newfoundland, Department of Fisheries and Oceans: 13 pp.

Trippel, E.A., M.B. Strong, J.M. Terhune and J.D. Conway. 1999. Mitigation of harbour porpoise (*Phocoena phocoena*) by-catch in the gillnet fishery in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 56 (1): 113-123.

UN [United Nations]. 1995. Agreement for the implementation of the provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the conservation and management of straddling fish stocks and highly migratory fish stocks: 40 pp.

UN [United Nations]. 2002. Plan of Implementation of the World Summit on Sustainable Development, Johannesburg, South Africa. General

Assembly of the United Nations document, 62 pp. Available online at: http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/-WSSD_PlanImpl.pdf.
UNCLOS. 1982. United Nations Convention on the Law of the Sea: 211 pp.
Wade, P.R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science 14: 1-37.
Walsh, D., B. Sjare and G.B. Stenson. 2000. Preliminary Estimates of Harp Seal By-catch in the Newfoundland Lumpfish Fishery. Canadian Stock Assessment Secretariat Research Document 2000/078. 16 pp.
Walsh, P.J. and W. Hiscock. 2005. Fishing for Atlantic Cod (*Gadus morhua*) using experimental baited pots. Results from trials in Placentia Bay & Fortune Bay, December 2003 & 2004, Newfoundland and Labrador, Canada. Centre for Sustainable Aquatic Resources, Fisheries & Marine Institute of Memorial University of Newfoundland, Report P-56: 45 pp.
Walsh, P.J., W. Hiscock and R. Sullivan. 2006. Fishing for Atlantic cod (*Gadus morhua*) using ecperimental baited pots. Centre for Sustainable Aquatic Resources, Fisheries & Marine Institute of Memorial University of Newfoundland, Report P-163: 26 pp.
Waring, G.T., R.M. Pace, J.M. Quintal, C.P. Fairfield, K. Maze-Foley, N. Cabana, P.J. Clapham, T.V.N. Cole, G.L. Fulling, L.P. Garrison, A.A. Hohn, B.G. Maise, W.E. McFee, K.D. Mullin, D.L. Palka, P.E. Rosel, M.C. Rossman, F.W. Wenzel and A.L. Whitingham. 2003. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments - 2003. NOAA Technical Memorandum NMFSNE-182: 287 pp.
Weeks, H. and S. Berkeley. 2000. Uncertainty and precautionary management of marine fisheries: Can the old methods fit the new mandates? Fisheries 25 (12): 6-15.

APPENDIX 1: SAMPLE CALCULATIONS

In this example, the data used originate from the nearshore cod gillnet fishery in NAFO unit 3Psc (Placentia Bay), during the third quarter of 2002. During this period, a total of 179 codfishing trips were recorded in this area by Bycatch Collectors and Sentinel fishers. Of these, 88 trips were made by 8 Sentinel fishers, and 91 trips by 6 Bycatch Collectors. Each trip has associated information on landed catch of cod (kg round weight) and net-days, as well as numbers of small cetaceans caught (if any). This leads to a series of incidental catch rates, as per Table A1-1.

All of these trip data are used to generate incidental catch ratios of "number of small cetaceans / kg catch" and "number of small cetaceans / net-day". The average value of all these incidental catch ratios becomes the multiplier with which to estimate incidental catch for the specific area and period. The uncertainty of the estimate is calculated by resampling the individual ratios 10,000 times, ranking the estimates and identifying the 2.5 % and 97.5 % values. These ratios will be used to calculate the limits of the confidence interval. As an example, the ratios for NAFO unit 3Psc during the third quarter of 2002 are shown in Table A1-2.

Table A1-1. Example of Bycatch Collector trip data used to estimate incidental catch of small cetaceans, during the third quarter of 2002, in Placentia Bay (NAFO Unit 3Psc). This particular set of data originated from a single Bycatch Collector. Note the variability in catch rates (kg catch / net-day) through time.

Date hauled	# nets fished	Soak time (# of days)	# of net-days	catch (kg round)	Species sought	# small cetaceans	small cetacean/ kg catch	small cetacean/ net-day	kg catch/ net-day
7/2/2002	20	7	140	551.4	Cod	1	0.00181	0.00714	3.93846
7/7/2002	20	5	100	641.2	Cod	0	0.00000	0.00000	6.41195
7/14/2002	20	7	140	508.9	Cod	0	0.00000	0.00000	3.63520
7/24/2002	20	7	140	716.3	Cod	0	0.00000	0.00000	5.11650
7/31/2002	20	7	140	538.9	Cod	1	0.00186	0.00714	3.84904
8/4/2002	20	4	80	447.4	Cod	0	0.00000	0.00000	5.59277
8/8/2002	20	4	80	414.2	Cod	0	0.00000	0.00000	5.17773
8/10/2002	20	2	40	268.3	Cod	1	0.00373	0.02500	6.70860
8/12/2002	20	2	40	414.8	Cod	0	0.00000	0.00000	10.36907
8/16/2002	20	4	80	252.0	Cod	0	0.00000	0.00000	3.15018
9/23/2002	16	1	16	407.7	Cod	0	0.00000	0.00000	25.48042
9/25/2002	16	2	32	635.2	Cod	0	0.00000	0.00000	19.85023
9/27/2002	16	2	32	981.4	Cod	0	0.00000	0.00000	30.66835

Total fishing effort for the area and time of interest is calculated from several DFO datasets. Landed catch is summed based on the total amount (round weight) of target species landed. Total numbers of net-days are based upon the ratio of kg landed catch per net-day, calculated from Bycatch Collectors, Sentinel fishers and, in the case of the cod fishery, effort data from the Groundfish Logbook programme. These ratios are combined and the resulting average ratio is used to estimate total number of net-days, based on total amount of landed catch.

Once the total amount of landed catch and estimated total number of net-days have been established, the incidental catch ratios can be used to estimate the total incidental catch of small cetaceans in the given area and time period, based on both landed catch and net-days. Data from adjacent areas can be combined for more wide-ranging estimates. When estimating incidental catch of small cetaceans, all data from adjacent NAFO units along the northeastern, southern and western coastlines were combined to calculate separate incidental catch ratios for each coastline.

Table A1-2. Example of ratios used to calculate incidental catches of small cetaceans. The present data refer to the nearshore cod fishery in NAFO unit 3PSc, during the third quarter of 2002.

Metric	Average estimate	Lower Confidence limit (2.5%)	Upper Confidence Limit (97.5%)
Small cetaceans / kg catch	0.00041	0.00004	0.00093
Small cetaceans / net-day	0.00204	0.00022	0.00484

APPENDIX 2: TABLES

Table 2.1. An overview of methodologies used to date to assess incidental capture of small cetaceans in commercial fisheries, as described in Chapter 2. Relative costs and utility of each method is indicated, and most important problems are summarized.

Data collection method	Cost (financial, effort)	Utility of data for incidental catch estimation	Potential problems
Observer programmes (dedicated to large marine vertebrates)	+++	+++	Degree of coverage, high costs, animals may be missed
Observer programmes (not dedicated to large marine vertebrates)	++	++	Lack of focus, degree of coverage, animals may be missed
Stranding surveys	+	+	Unknown what fraction of captured animals strand; cause of death often unknown
Reporting schemes (voluntary)	+	+	No inducement for fishers to report; no accompanying fishing effort data
Reporting schemes (mandatory)	++	+	Unpopular with fishers; potential for underreporting
Carcass salvage schemes	++ / +++	+	Only minimum estimates; limiting logistical factors; high costs
Interviews (mailed questionnaires)	+	++	Usually low returns; seasonal fluctuations
Interviews (telephone)	++	++	Potential for bias in selection of available fishers
Interviews (face-to-face)	+++	+++	Potential for bias in selection of available fishers; trust may take years to develop
Logbook analysis	++	++ / +++	Potential for bias in selection of available fishers; trust may take years to develop

Table 3.1. Incidental catch estimates for the 2002 nearshore cod gillnet fishery at increasing geographic scale, based on fishers as sampling units, using net-days and kg landed catch as measures of fishing effort.

		PER FISHER Estimated incidental catch per net-day		PER FISHER Estimated incidental catch per kg landed catch	
	Quarter	Estimate	95% C.I.	Estimate	95% C.I.
NAFO unit	1	0	not resampled	0	not resampled
NAFO unit	2	132	not resampled	690	not resampled
NAFO unit	3	661	not resampled	1,854	not resampled
NAFO unit	4	3	not resampled	8	not resampled
TOTAL		796		2,551	
Coastline	1	0	0 - 0	0	0 - 0
Coastline	2	351	not resampled	1,072	not resampled
Coastline	3	1,100	not resampled	3,430	not resampled
Coastline	4	31	not resampled	266	not resampled
TOTAL		1,482		4,768	
Whole island	1	0	not resampled	0	not resampled
Whole island	2	125	7 - 337	1,613	12 - 4505
Whole island	3	1,115	263-2,244	3,161	387-7,682
Whole island	4	198	0 - 497	788	0-2,318
TOTAL		1,438	270-3,078	5,561	398-14,505

Table 3.2. Incidental catch estimates for the 2002 nearshore cod gillnet fishery at increasing geographic scale, based on trips per fisher as sampling units, using net-days and kg landed catch as measures of fishing effort.

		PER TRIP PER FISHER Estimated incidental catch per net-day		PER TRIP PER FISHER Estimated incidental catch per kg landed catch	
	Quarter	Estimate	95% C.I.	Estimate	95% C.I.
NAFO unit	1	0	0 - 0	0	0 - 0
NAFO unit	2	131	N/A	100	N/A
NAFO unit	3	764	N/A	3,257	N/A
NAFO unit	4	3	0 - 8	85	0 - 254
TOTAL		898	N/A	3,441	N/A
Coastline	1	0	0 - 0	0	0 - 0
Coastline	2	181	0-551	141	0-423
Coastline	3	1,088	365-1,997	5,986	1,584-12,672
Coastline	4	28	0 - 84	567	0-1,700
TOTAL		1,296	365-2,632	6,676	1,584-14,796
Whole island	1	0	0 - 0	0	0 - 0
Whole island	2	236	21 - 533	4,472	7-11,006
Whole island	3	872	407 – 1,401	5,099	1,694-9,792
Whole island	4	89	0 - 264	3,243	0-9,342
TOTAL		1,197	428-2,198	12,814	1,701-30,140

Table 4.1. Total landed catches for various Newfoundland gillnet fisheries (mt, round weight) in 2001, 2002 and 2003, together with amounts of landed catch reported by Bycatch Collectors and Fishery Observers, respectively. 'Not fished' indicates that no Bycatch Collector was active in this fishery during a given year.

Fishery	Total Catch (mt), per year			Bycatch Collector reported fraction of catch (mt)						Fishery Observer reported fraction of catch (mt)					
	2001	2002	2003	2001	% of total catch	2002	% of total catch	2003	% of total catch	2001	% of total catch	2002	% of total catch	2003	% of total catch
Cod (nearshore)	10,264	10,233	6,284	90.9	0.9	124.5	1.2	88.1	1.4	97.0	0.9	60.3	0.6	31.5	0.5
Cod (offshore)	1,394	1,913	1,780	not fished	not fished	not fished	not fished	not fished	not fished	78.7	5.6	113.4	5.9	112.7	6.3
Lumpfish (nearshore)	872	171	554	23.1	2.6	5.7	3.3	11.9	2.1	6.9	0.8	2.2	1.3	12.1	2.2
Herring (nearshore)	1,430	1,660	1,025	59.8	4.2	60.1	3.6	19.2	1.9	1.0	0.1	0.0	0.0	0.0	0.0
Monkfish/skate (offshore)	942	3,027	2,659	57.3	6.1	32.0	1.1	1.8	0.1	284.3	30.2	1,116.3	36.9	1,052.4	39.6
White hake (offshore)	305	345	278	not fished	not fished	not fished	not fished	not fished	not fished	21.1	6.9	62.1	18.0	35.6	12.8
Greenland halibut (nearshore)	1,687	868	1,321	19.3	1.1	1.5	0.2	23.2	1.8	56.1	3.3	6.0	0.7	4.7	0.4
Greenland halibut (offshore)	7,237	5,277	3,517	not fished	not fished	not fished	not fished	not fished	not fished	219.4	3.0	375.3	7.1	107.5	3.1
Redfish (nearshore/offshore)	447	337	486	10.1	2.3	6.3	1.9	not fished	not fished	1.7	0.4	9.5	2.8	5.6	1.2
Winter flounder (nearshore)	504	340	205	0.6	0.1	2.3	0.7	2.8	1.3	2.7	0.5	0.9	0.3	1.4	0.7

Table 4.2. Total fishing effort (net-days, estimated) for various Newfoundland gillnet fisheries in 2001, 2002 and 2003, together with amounts of fishing effort reported by Bycatch Collectors and Fishery Observers, respectively. 'Not fished' indicates that no Bycatch Collector was active in this fishery during a given year.

Fishery	Fishing Effort (Net-days, estimated), per year			Bycatch Collector reported fraction of netdays						Fishery Observer reported fraction of netdays					
	2001	2002	2003	2001	% of total	2002	% of total	2003	% of total	2001	% of total	2002	% of total	2003	% of total
Cod (nearshore)	907,309	1,073,606	793,147	6,491	0.7	8,657	0.8	6,759	0.9	4,763	0.5	4,412	0.4	4,141	0.5
Cod (offshore)	14,299	22,256	17,546	not fished	not fished	not fished	not fished	not fished	not fished	769	5.4	848.2	3.8	960.9	5.5
Lumpfish (nearshore)	218,263	123,315	126,353	22,251	10.2	12,791	10.4	15,904	12.6	1,686	0.8	1,429	1.2	2,184	1.7
Herring (nearshore)	32,073	23,052	14,140	627	2.0	640	2.8	1,116	7.9	35	0.1	0	0.0	0	0.0
Monkfish/skate (offshore)	154,467	251,575	211,549	2,550	1.7	1,224	0.5	280	0.1	25,154	16.3	91,017	36.2	62,757	29.7
White hake (offshore)	5,907	12,371	9,989	not fished	not fished	not fished	not fished	not fished	not fished	419	7.1	2,049.0	16.6	1,485	14.9
Greenland halibut (nearshore)	416,933	315,928	1,695,817	3,329	0.8	2,497	0.8	4,606	0.3	8,255	2.0	4,260	1.3	1,568	0.1
Greenland halibut (offshore)	2,563,700	2,135,685	6,674,892	not fished	not fished	not fished	not fished	not fished	not fished	102,511	4.0	145,693	6.8	45,456	0.7
Redfish (nearshore/offshore)	82,024	23,444	68,054	388	0.5	520	2.2	not fished	not fished	313	0.4	664	2.8	783	1.2
Winter flounder (nearshore)	31,216	80,283	65,141	108	0.3	349	0.4	611	0.9	157	0.5	173	0.2	149	0.2

Table 4.3: Geographic distribution of Bycatch Collectors and Sentinel fishers during 2001-2003.

Fishery	Number of Bycatch Collectors			Number of Sentinel fishers		
	2001	2002	2003	2001	2002	2003
3Ka		1		1	1	1
3Kd	3	3	3	7	6	5
3Kh	2	2	2	7	7	6
3Ki	2	3	1	10	10	8
3La	3	2	1	5	5	3
3Lb	1	2	1	5	5	4
3Lf	1	1	1	5	5	3
3Lj				7	7	4
3Lq	2	1		4	4	4
3Pn	2	2	2			
3Psa	1	2	1		1	
3Psb	5	4	4	2	2	2
3Psc	5	6	4	9	9	7
4Ra	2	1	2	11	11	6
4Rb	2	3	1	4	4	3
4Rc	1	1	1	2	3	1
4Rd	1		1	2	1	1
TOTAL	33	34	25	81	81	58

Table 4.4: An overview of small cetacean incidental catch events recorded by the Bycatch Collector and Sentinel programme, and the Fishery Observer programme, during 2001-2003. Dashes indicate no fishing effort was observed.

Fishery	Number of small cetacean catch events per year, reported by Bycatch Collectors (and Sentinel fishers, for the cod fishery)			Number of small cetacean catch events per year, reported by Fishery Observers		
	2001	2002	2003	2001	2002	2003
Cod (nearshore)	23	47	21	8	2	0
Cod (offshore)	0	0	0	0	0	0
Lumpfish (nearshore)	11	0	13	0	0	0
Herring (nearshore)	5	0	1	0	0	–
Monkfish/skate (offshore)	0	3	0	1	21	3
White hake (offshore)	–	–	–	0	1	0
Greenland halibut (nearshore)	0	3	0	0	0	0
Greenland halibut (offshore)	0	–	–	1	0	0
TOTAL	39	53[1]	35	10	24	3

[1] The total number of small cetaceans reported to DFO in 2002 was 64. Eleven of these were brought in by fishers who had no affiliation with either the Sentinel fishery, or the Bycatch Collector programme, but who became aware of DFO's collection efforts through word of mouth. Ten had been caught in the nearshore cod fishery, while one was caught in a lumpfish gillnet.

Table 4.5: Estimated catches of small cetaceans in nearshore and offshore gillnet fisheries in all areas of the island of Newfoundland, based on net-days, for 2001 – 2003. 'N/A' indicates that no confidence interval could be calculated due to small sample size.

Fishery	Scale	Quarter	2001 Estimate	2001 95% C.I.	2002 Estimate	2002 95% C.I.	2003 Estimate	2003 95% C.I.
Cod nearshore	Coastline	1	0	0 – 0	0	0 – 0	0	0 – 0
		2	119	0 – 273	181	0 – 551	1,467	286 – 3,149
		3	570	102 – 1,443	1,088	365 – 1,997	534	9 – 1,529
		4	0	0 – 0	28	0 – 84	0	0 – 0
Cod TOTAL			688	102 – 1,715	1,296	365 – 2,632	2,001	295 – 4,678
Lumpfish nearshore	Coastline	Whole year	84	2 – 240	0[1]	0[1]	211	20 – 499
Herring nearshore	Coastline	3	89	26 – 176	0	0	10	0 – 29
Greenland halibut nearshore	Coastline	2	0	0	1	N/A	0	0
		3	0	0	28	0 – 78	0	0
Greenland halibut TOTAL					29	N/A		
Monkfish and skate offshore	3OPs offshore	Whole year	1	0 – 4	60	32 – 92	6	0 – 17
White hake offshore	3OPs offshore	Whole year	0	0	43	N/A	0	0
GRAND TOTAL			862	160 – 1,808	1,428	N/A	2,228	315 – 5,223

[1] No Bycatch Collectors reported harbour porpoise incidental catch in their 2002 lumpfish fishery; however, a single animal was reported by a fisher who was unaffiliated with the programme.

Table 4.6. Ages of incidentally caught harbour porpoises collected by DFO technicians during 2001-2003. Ages were determined as described in Chapter 4.

2-Year age bin	Year					
	2001		2002		2003	
	Female	Male	Female	Male	Female	Male
0-<2	2	3	2	4	0	3
2-<4	3	3	7	3	9	3
4-<6	7	5	2	6	1	3
6-<8	1	1	5	3	5	1
8-<10	2	2	2	5	1	4
10-<12	1	0	0	1	1	0
12-<14	1	0	1	1	0	0
Total	17	14	19	23	17	14

Table 5.1. Reported catches of various seal species in gillnet fisheries, 2001-2003, based on Bycatch Collector data.

Pg = Harp seal, Cc = Hooded seal, Hg = grey seal, Pv = harbour seal, Ph = ringed seal; Eb = bearded seal.

Fishery		Number of seal catch events per year, reported by Bycatch Collectors																	
		2001						2002						2003					
		Pg	Cc	Hg	Pv	Ph	Eb	Pg	Cc	Hg	Pv	Ph	Eb	Pg	Cc	Hg	Pv	Ph	Eb
Cod (nearshore)	NCI	16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SCI	10	1	0	4	0	0	29	0	0	0	0	0	6	0	0	0	0	0
	WCI	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumpfish (nearshore)	NCI	58	0	0	0	5	2	81	1	0	0	5	0	23	0	0	0	5	0
	SCI	71	2	2	4	0	0	16	0	0	0	0	0	66	0	0	0	1	0
	WCI	393	7	2	2	0	4	33	0	0	1	2	2	26	0	0	0	0	0
Herring (nearshore)	NCI	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenland halibut (nearshore)	SCI	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winter flounder	NCI	0	0	0	0	0	0	3	0	0	0	1	0	2	0	0	0	0	0

Table 5.2. Reported catches of various seal species in gillnet fisheries, 2001-2003, based on Fishery Observer data. Pg = Harp seal, Cc = Hooded seal, Hg = grey seal, Pv = harbour seal, Ph = ringed seal; Eb = bearded seal.

Fishery		Number of seal catch events per year, reported by Fishery Observers																	
		2001						2002						2003					
		Pg	Cc	Hg	Pv	Ph	Eb	Pg	Cc	Hg	Pv	Ph	Eb	Pg	Cc	Hg	Pv	Ph	Eb
Cod (nearshore)	SCI	1	0	0	1	0	0	7	0	0	0	0	0	1	0	0	0	0	0
	WCI	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cod (offshore)	3OPs	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Lumpfish (nearshore)	NCI	1	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0
	SCI	0	0	0	7	0	0	0	0	0	0	0	0	6	0	1	2	0	0
Monkfish/skate (offshore)	3OPs	17	0	0	0	0	0	12	0	1	2	0	0	6	0	0	0	0	0
Greenland halibut (offshore)	2GHJ3K	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Table 5.3. Incidental catch estimates of various seal species in gillnet fisheries, 2001-2003, based on Bycatch Collector data.

Fishery	Year	Incidental catch estimates (Bycatch Collectors)											
		Harp seal		Hooded seal		Grey seal		Harbour seal		Ringed seal		Bearded seal	
Cod (nearshore)	2001	3,234	N/A	90	0-273	0		115	0-319	0		0	
	2002	1,218	345-2,279	0		0		0		0		0	
	2003	364	0-1,002	0		0		0		0		0	
Lumpfish (nearshore)	2001	23,379	14,983-33,078	322	15-887	273	0-794	622	0-1,696	430	79-859	190	0-516
	2002	9,342	N/A	428	0-1,283	0		8	0-24	338	78-672	13	0-33
	2003	9,321	2,226-19,294	0		0		0		1,077	126-2,531	0	
Herring (nearshore)	2001	168	N/A	713	N/A	0		0		0		0	
Greenland halibut (nearshore)	2001	58	N/A	0		0		0		0		0	
Winter flounder	2002	40	0-86	0		0		0		11	0-34	0	
	2003	32	0-79	0		0		0		0		0	

Table 5.4. Incidental catch estimates of various seal species in gillnet fisheries, 2001-2003, based on Fishery Observer data.

Fishery	Year	Incidental catch estimates (Fishery Observers)							
		Harp seal		Hooded seal		Grey seal		Harbour seal	
Cod (nearshore)	2001	448	0-1,121	0		0		143	0-445
	2002	425	120-837	0		0		0	
	2003	43	0-134	0		0		0	
Cod (offshore)	2002	55	0-169	0		0		0	
Lumpfish (nearshore)	2001	119	0-378	0		0		629	181-1,088
	2002	250	0-500	249	0-500	0		61	0-153
	2003	182	61-337	0		32	0-92	0	
Monkfish/skate (offshore)	2001	18	4-35	0		0		0	
	2002	23	3-48	0		3	0-10	3	0-9
	2003	10	1-21	0		0		0	
Greenland halibut (offshore)	2002	2	0-6	0		0		0	

Table 6.1. Reported catches of various seabird species in gillnet fisheries, 2001-2003, based on Bycatch Collector data. Mu = Murres (*Uria* sp.); Rz = Razorbill; Bg = Black Guillemot; Lo = Loons (*Gavia* sp.); Dc = Double-crested cormorant; Ga = Gannet; Su = Shearwaters (unidentified).

Fishery			2001							2002							2003						
	Area	Quarter	Mu	Rz	Bg	Lo	Dc	Ga	Su	Mu	Rz	Bg	Lo	Dc	Ga	Su	Mu	Rz	Bg	Lo	Dc	Ga	Su
Cod (nearshore)	NCI	3rd	18	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-
	SCI	2nd	2	0	0	0	0	0	0	14	0	0	0	0	0	0	3	0	0	0	0	0	0
		3rd	9	0	0	0	0	0	20	6	0	0	0	0	0	0	13	0	0	0	0	0	0
	WCI	2nd	1	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3rd	0	0	0	0	0	0	0	1	0	0	0	0	0	0	-	-	-	-	-	-	-
Lumpfish (nearshore)	NCI	all	14	0	5	1	0	0	0	2	0	3	2	0	0	0	2	0	0	0	0	0	0
	SCI	all	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WCI	all	2	3	2	0	0	0	0	22	7	0	0	0	0	0	0	0	0	0	0	0	0
Greenland halibut (nearshore)	NCI	3rd	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winter flounder (nearshore)	NCI	2nd	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	0	0	1	0

Table 6.2. Incidental catch events of various seabird species in gillnet fisheries, 2001-2003, based on Fishery Observer data. Mu = Murres (*Uria* sp.); Pu = Atlantic Puffin; Do = Dovekie; Lo = Loons (*Gavia* sp.); Dc = Double-crested cormorant; Ga = Northern Gannet; Gs = Greater shearwater; Ss = Sooty shearwater; Cs = Cory's shearwater; Sh = Shearwaters (unidentified); Fu = Northern Fulmar; Ei = Eider duck. NC = northeast coast, SC = south coast; WC = west coast; ns = nearshore, os = offshore. Note: an event may involve more than one individual.

Fishery	Area	Quarter	2001										2002				2003					
			Mu	Pu	Lo	Dc	Ga	Gs	Ss	Cs	Su	Fu	Mu	Gs	Ss	Su	Mu	Do	Gs	Ss	Su	Ei
Cod (ns)	NC	3rd	14	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SC	2nd	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		3rd	4	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		4th	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cod (os)	3OPs	2nd	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
		3rd	0	0	0	0	0	0	0	0	0	0	0	27	1	0	0	0	3	0	0	0
		4th	0	0	0	0	0	0	0	0	0	0	7	0	0	1	1	0	0	0	0	0
Lumpfish (ns)	NC	all	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SC	all	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Monkfish/Skate os)	3OPs	all	0	0	0	0	0	8	2	0	4	0	0	22	2	20	0	0	6	4	3	0
White hake (os)	3OPs	all	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Greenland halibut (ns)	NC	3rd	2	0	0	0	0	0	1	2	0	2	0	0	0	0	0	0	0	0	0	0
Greenland halibut (os)	2GHJ3K	3rd	0	0	0	0	1	0	1	0	0	4	0	4	0	0	0	0	0	0	0	0
	3LN	3rd	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	3OPs	2nd	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
		3rd	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0

Table 6.3. Estimated catches of various seabird species in gillnet fisheries, 2001-2003, based on Bycatch Collector data. Mu = Murres (*Uria* sp.); Rz = Razorbill; Bg = Black Guillemot; Lo = Loons (*Gavia* sp.); Dc = Double-crested cormorant; Ga = Gannet; Su = Shearwaters (unidentified). NC = northeast coast, SC = south coast; WC = west coast.

Fishery	Year	Quarter	Area	Mu	C.I.	Rz	C.I.	Bg	C.I.	Lo	C.I.	Dc	C.I.	Ga	C.I.	Su	C.I.
Cod (nearshore)	2001	2nd	SC	65	0-195	0	0	0	0	0	0	0	0	0	0	0	0
			WC	104	N/A	0	0	0	0	0	0	0	0	0	0	0	0
		3rd	NC	5,559	N/A	0	0	0	0	0	0	0	0	0	0	0	0
			SC	1,980	N/A	0	0	0	0	0	0	0	0	0	0	710	0-1,802
	2002	2nd	SC	1,180	N/A	0	0	0	0	0	0	0	0	0	0	0	0
		3rd	SC	88	0-236	0	0	0	0	0	0	0	0	0	0	0	0
			WC	166	0-498	0	0	0	0	0	0	0	0	0	0	0	0
	2003	2nd	SC	279	0-747	0	0	0	0	0	0	0	0	0	0	0	0
		3rd	SC	1,190	0-2,998	0	0	0	0	0	0	0	0	0	0	0	0
Lumpfish (nearshore)	2001	all	NC	998	N/A	0	0	233	47-471	39	0-119	0	0	0	0	0	0
			SC	279	N/A	0	0	0	0	0	0	1	0-4	0	0	0	0
			WC	10	N/A	18	0-41	19	0-50	48	1-108	0	0	0	0	0	0
	2002	all	NC	1,954	N/A	0	0	109	0-323	27	0-81	0	0	0	0	0	0
			WC	12	N/A	7	N/A	0	0	0	0	0	0	0	0	0	0
	2003	all	NC	608	N/A	0	0	0	0	0	0	0	0	0	0	0	0
Greenland halibut (nearshore)	2001	3rd	NC	2	N/A	0	0	0	0	0	0	0	0	0	0	0	0
Winter flounder (nearshore)	2002	2nd	NC	0	0	0	0	0	0	17	0-52	0	0	0	0	0	0
	2003	2nd	NCI	16	0-44	0	0	0	0	0	0	0	0	8	0-24	0	0

Table 6.4. Incidental catch events[2] of various seabird species in gillnet fisheries, 2001-2003, based on Fishery Observer data (Part 1). Mu = Murres (*Uria* sp.); Pu = Atlantic Puffin; Do = Dovekie; Lo = Loons (*Gavia* sp.); Dc = Double-crested cormorant; Ga = Northern Gannet; Ei = Eider duck. NC = northeast coast, SC = south coast; WC = west coast; ns = nearshore, os = offshore.

Fishery	Year	Quarter	Area	Mu	95% C.I.	Pu	95% C.I.	Do	95% C.I.	Lo	95% C.I.	Dc	95% C.I.	Ga	95% C.I.	Ei	95% C.I.
Cod (ns)	2001	2nd	SC											78	N/A		
		3rd	NC	9,888	10,919-25,240	649	97-1,358										
			SC	2,349	60-6,051												
		4th	SC	58	0-177							136	0-392				
Cod (os)	2002	4th	3Ps	72	0-197												
	2003	4th	3Ps	4	N/A												
Lumpfish (ns)	2001	all	NC							384	0-1,138						
	2003	all	SC													26	0-774
Greenland halibut (os)	2001	3rd	2GHJ3K											96	0-249		
	2003	2nd	3OPs					22	N/A								
Winter flounder (ns)	2001	3rd	SC											171	N/A		

[2] Note: an event may involve more than one individual.

Table 6.5. Incidental catch events[3] of various seabird species in gillnet fisheries, 2001-2003, based on Fishery Observer data (Part 2). Gs = Greater shearwater; Ss = Sooty shearwater; Cs = Cory's shearwater; Sh = Shearwaters (unidentified); Fu = Northern Fulmar. NC = northeast coast, SC = south coast; WC = west coast; ns = nearshore, os = offshore.

Fishery	Year	Quarter	Area	Gs	95% C.I.	Ss	95% C.I.	Cs	95% C.I.	Su	95% C.I.	Fu	95% C.I.
Cod (ns)	2001	3rd	SC	205	0-615								
	2002	3rd	SC	120	0-360								
Cod (os)	2002	3rd	3Ps	909	N/A	89	N/A						
		4th	3Ps	3,139	653-6,382					22	0-56		
	2003	4th	3Ps	119	N/A								
Monkfish/Skate (os)	2001	all	3OPs	81	0-192	8	0-23			47	0-118		
	2002	all	3OPs	263	33-605	7	0-17			286	17-770		
	2003	all	3OPs	45	0-134	6	0-19			44	0-156		
White hake (os)	2001	all	3OPs	211	N/A								
	2002		3OPs	7	N/A								
Greenland halibut (ns)	2001	3rd	NC			222	0-641	222	0-641			222	0-641
Greenland halibut (os)	2001	3rd	2GHJ3K			37	0-115					75	0-193
		3rd	3LN					246	N/A				
		3rd	3OPs	66	N/A								
	2002	2nd	3OPs							2	N/A		
		3rd	2GHJ3K	90	N/A								
Winter flounder (ns)	2001	3rd	SC			62	N/A						

[3] Note: an event may involve more than one individual.

Table 7.1. Incidental catch events of shark and other species in gillnet fisheries, 2001-2003, based on Bycatch Collector data. Bl = Blue shark, Ba = Basking shark; Sp = Spiny dogfish; Us = Unknown shark; As = Atlantic sturgeon; Os = Ocean sunfish. NC = northeast coast, SC = south coast; WC = west coast.

Fishery	Area	Quarter	2001					2002			2003		
			Bl	Ba	Sp	Us	As	Sp	As	Os	Sp	Us	As
Cod (nearshore)	NC	3rd		5			2		1				
		4th			2								
	SC	2nd						11					
		3rd	1		3			12				3	1
		4th	1					1				2	
	WC	3rd				1		4					
		4th									1		
Lumpfish (nearshore)	SC	all											1
	WC	all								1			
Herring (nearshore)	WC	3rd				1							
Greenland halibut (nearshore)	NC	3rd				1							
	SC	3rd						1					

Table 7.2. Incidental catch events of shark and other species in gillnet fisheries, 2001, based on Fishery Observer data. Pb = Porbeagle, Bl = Blue shark, Sm = Shortfin mako; Ba = Basking shark; Gr = Greenland shark; Sp = Spiny dogfish; Bd = Black dogfish; Dc = Deepsea catshark; Ps = Portuguese shark; Sw = Swordfish. NC = northeast coast, SC = south coast; WC = west coast. Values refer to numbers of animals unless indicated otherwise.

Fishery	Area	Quarter	Pb	Bl	Sm	Ba	Gr	Sp	Bd	Dc	Ps	Sw
Cod (nearshore)	SC	1st										
		2nd						178 kg	3 kg			
		3rd	1					4 kg	12 kg			
		4th										
Cod (offshore)	3OPs	3rd						1 kg				
		4th	4									
Lumpfish (nearshore)	SCI	all						7 kg				
Monkfish/Skate (offshore)	3OPs	all	2	2	3		2 kg	17 kg	1 kg			
White hake (offshore)	3OPs	all					20 kg	27 kg				1
Greenland halibut (nearshore)	NC	3rd						2 kg				
Greenland halibut (offshore)	2GHJ3K	2nd					2,634 kg		245 kg	2 kg		
		3rd				1			2,841 kg		16 kg	
	3LN	3rd							2 kg			
	3OPs	1st							548 kg			
		2nd					1,050 kg		3,235 kg	260 kg		
		4th							1,048 kg			
Redfish (nearshore)	SCI	3rd	1					318 kg				

Table 7.3. Incidental catch events of shark and other species in gillnet fisheries, 2002, based on Fishery Observer data. Pb = Porbeagle, Bl = Blue shark, Sm = Shortfin mako; Th = Thresher shark; Ba = Basking shark; Gr = Greenland shark; Sp = Spiny dogfish; Bd = Black dogfish; Ps = Portuguese shark; Sw = Swordfish. NC = northeast coast, SC = south coast; WC = west coast. Values refer to numbers of animals unless indicated otherwise.

Fishery	Area	Quarter	Pb	Bl	Sm	Th	Ba	Gr	Sp	Bd	Ps	Sw
Cod (nearshore)	SC	1st							7 kg			
		2nd							2 kg			
		3rd	1	1	1				429 kg			
		4th										
Cod (offshore)	3OPs	3rd							2 kg			
		4th	1	4	1	1						
Monkfish/Skate (offshore)	3OPs	all	4	4	2		5	2734 kg	17 kg	25 kg		
White hake (offshore)	3OPs	all		1			1		210 kg			2
Greenland halibut (offshore)	2GHJ3K	2nd					4	12430 kg	20 kg	834 kg	30 kg	
		3rd					2		109 kg	338 kg		
	3LN	2nd							55 kg			
		3rd						1816 kg		35 kg		
	3OPs	2nd						750 kg		1845 kg		
		3rd								100 kg		
		4th						450 kg		385 kg		
Redfish (nearshore)	SCI	3rd	2						554 kg	4 kg		

Table 7.4. Incidental catch events of shark and other species in gillnet fisheries, 2003, based on Fishery Observer data. Pb = Porbeagle, Bl = Blue shark, Sm = Shortfin mako; Th = Thresher shark; Ba = Basking shark; Sp = Spiny dogfish; Bd = Black dogfish; Ps = Portuguese shark; Dc = Deepsea catshark; Sw = Swordfish; Os = Ocean sunfish. NC = northeast coast, SC = south coast; WC = west coast. Values refer to numbers of animals unless indicated otherwise.

Fishery	Area	Quarter	Pb	Bl	Sm	Th	Ba	Sp	Bd	Ps	Sw	Os
Cod (nearshore)	SC	2^{nd}						61 kg				
		3^{rd}						42 kg				
		4^{th}				1		16 kg				
Cod (offshore)	3OPs	3^{rd}		3	4							
		4^{th}	1		6			22 kg				
Monkfish/Skate (offshore)	3OPs	all	9	6	9		4	13 kg	12 kg			
White hake (offshore)	3OPs	all						18 kg	2 kg		1	
Greenland halibut (offshore)	2GHJ3K	3^{rd}			1				120 kg			
	3OPs	2^{nd}	1						1545 kg			
		3^{rd}							435 kg			
Redfish (nearshore)	SCI	3^{rd}			1			5 kg				1

Table 7.5. Incidental catch estimates of shark and other species in gillnet fisheries, 2001-2003, based on Bycatch Collector data. Bl = Blue shark, Ba = Basking shark; Sp = Spiny dogfish; Us = Unknown shark; As = Atlantic sturgeon; Os = Ocean sunfish. NC = northeast coast, SC = south coast; WC = west coast. N/A indicates that no confidence interval could be calculated. Values refer to numbers of animals.

Fishery	Area	2001										2002						2003					
		Bl	95% C.I.	Ba	95% C.I.	Sp	95% C.I.	Us	95% C.I	As	95% C.I	Sp	95% C.I.	As	95% C.I.	Os	95% C.I.	Sp	95% C.I.	Us	95% C.I.	As	95% C.I.
Cod (nearshore)	NC	0		429	64 - 941	511	N/A	0		292	0 -834	0		79	0 -238	0		0		0		0	
	SC	306	0 -919	0		346	0 - 806	0		0		2,766	0 - 8181	0		0		623	174 - 1,274	229	N/A	42	0 -127
	WC	0		0		0		2	0-6	0		276	0 - 719	0		0		5	0-17	0		0	
Lumpfish (nearshore)	SC	0		0		0		0		0		0		0		4	0 -13	0		0		0	
	WC	0		0		0		0		0		0		0		0		0		0		6	0-19
Herring (nearshore)	WC	0		0		0		15	0 -43	0		0		0		0		0		0		0	
Greenland halibut (nearshore)	NC	0		0		0		139	N/A	0		0		0		0		0		0		0	

Table 7.6. Incidental catch estimates of shark and other species in gillnet fisheries, 2001, based on Fishery Observer data. Pb = Porbeagle, Bl = Blue shark, Sm = Shortfin mako; Ba = Basking shark; Gr = Greenland shark; Sp = Spiny dogfish; Bd = Black dogfish; Dc = Deepsea catshark; Ps = Portuguese shark; Sw = Swordfish. NC = northeast coast, SC = south coast; WC = west coast. Underlined values refer to total weight caught.

Fishery	Area	Pb	95% C.I.	Bl	95% C.I.	Sm	95% C.I.	Ba	95% C.I.	Gr (kg)	95% C.I.	Sp (kg)	95% C.I.	Bd (kg)	95% C.I.	Dc (kg)	95% C.I.	Ps (kg)	95% C.I.	Sw	95% C.I.
Cod (nearshore)	SC	80	0 - 234	0		0		0		0		10,679	3,847-19,734	939	117 - 2,277	0		0		0	
Cod (offshore)	3OPs	58	15-118	0		0		0		0		15	0-44	0		0		0		0	
Lumpfish (nearshore)	SCI	0		0		0		0		0		634	0-1,904	0		0		0		0	
Monkfish/Skate (offshore)	3OPs	2	0-7	6	0-18	8	0-22	0		8	0-23	95	13-234	4	0-12	0		0		0	
White hake (offshore)	3OPs	0		0		0		0		283	N/A	381	N/A	0		0		0		14	N/A
Greenland halibut (nearshore)	NC	0		0		0		0		0		43	0-123	0		0		0		0	
Greenland halibut (offshore)	2GHJ3K	0		0		0		24	0-71	64,737	3,235 - 140,376	0		79,887	0-125,568	48	0-143	378	0-858	0	
	3LN	0		0		0		0		0		141	0-408	0		768	119-1,665	0		0	
	3OPs	0		0		0		0		3,144	0 -8,325	0		12,853	9,782-16,465	0		0		0	
Redfish (nearshore)	SCI	261	N/A	0		0		0		0		83,114	N/A	0		0		0		0	

Table 7.7. Incidental catch estimates of shark and other species in gillnet fisheries, 2002, based on Fishery Observer data. Pb = Porbeagle, Bl = Blue shark, Sm = Shortfin mako; Ba = Basking shark; Th = Thresher shark; Gr = Greenland shark; Sp = Spiny dogfish; Bd = Black dogfish; Ps = Portuguese shark; Sw = Swordfish. NC = northeast coast, SC = south coast; WC = west coast. Underlined values refer to total weights caught.

Fishery	Area	Pb	95% C.I.	Bl	95% C.I.	Sm	95% C.I.	Ba	95% C.I.	Th	95% C.I.	Gr (kg)	95% C.I.	Sp (kg)	95% C.I.	Bd (kg)	95% C.I.	Ps (kg)	95% C.I.	Sw	95% C.I.
Cod (nearshore)	SC	265	0-789	264	0-789	275	0-789	0		0		0		113,591	13,672-280,113	0		0		0	
Cod (offshore)	3OPs	6	0-19	26	6-51	6	0-19	6	0-19	0		0		13	0-39	0		0		0	
Monkfish (offshore)	3OPs	289	0-862	11	2-23	3	0-9	395	2-1,125	0		10,291	0 - 25,670	3,278	20-9,341	41	9-85	0		17	2-37
White hake (offshore)	3OPs	0		5	0-17	0		0		5	0-17	0		1,176	786-1,606	0		0		11	0-28
Greenland halibut (offshore)	2GHJ3K	0		0		0		0		73	9-166	110,225	2,316-298,954	2,165	1,009-3,787	13,940	9,218-19,013	288	0-695	0	
	3LN	0		0		0		0		0		45,739	0-144,833	1,467	399-2,791	925	319-1,622	0		0	
	3OPs	0		0		0		0		0		1,909	0-5,681	0		6,110	3,950-8,610	0		0	
Redfish (nearshore)	SCI	68	0-175	0		0		0		0		0		19,104	3,404-47,040	141	0-421	0		0	

Table 7.8. Incidental catch estimates of shark and other species in gillnet fisheries, 2003, based on Fishery Observer data. Pb = Porbeagle, Bl = Blue shark, Sm = Shortfin mako; Ba = Basking shark; Th = Thresher shark; Sp = Spiny dogfish; Bd = Black dogfish; Ps = Portuguese shark; Sw = Swordfish; Os = Ocean sunfish. NC = northeast coast, SC = south coast; WC = west coast. Underlined values refer to total weights caught.

Fishery	Area	Pb	95% C.I.	Bl	95% C.I.	Sm	95% C.I.	Ba	95% C.I.	Th	95% C.I.	Sp (kg)	95% C.I.	Bd (kg)	95% C.I.	Sw	95% C.I.	Os	95% C.I.
Cod (nearshore)	SC	0		0		0		0		205	0-645	28,236	8,693-52,388	0		0		0	
Cod (offshore)	3OPs	4	0-13	22	4-44	164	43-318	0		0		98	0-229	0		0		0	
Monkfish/Skate (offshore)	3OPs	17	3-35	17	0-43	15	3-34	9	0-25	0		37	0-110	37	0-110	0		0	
White hake (offshore)	3OPs	0		0		0		0		0		119	20-249	13	0-40	7	0-20	0	
Greenland halibut (nearshore)	NC	0		0		0		0		0		361	0-1,092	0		0		0	
Greenland halibut (offshore)	2GHJ3K	0		0		0		0		0		0		3,720	1,886-6,028	0		0	
	3LN	0		0		0		0		0		0		0		0		0	
	3OPs	2	0-7	0		2	0-7	0		0		0		4,874	3,072-7,246	0		0	
Redfish (nearshore)	SCI	75	N/A	0		0		0		0		375	N/A	0		0		75	N/A

APPENDIX 3: FIGURES

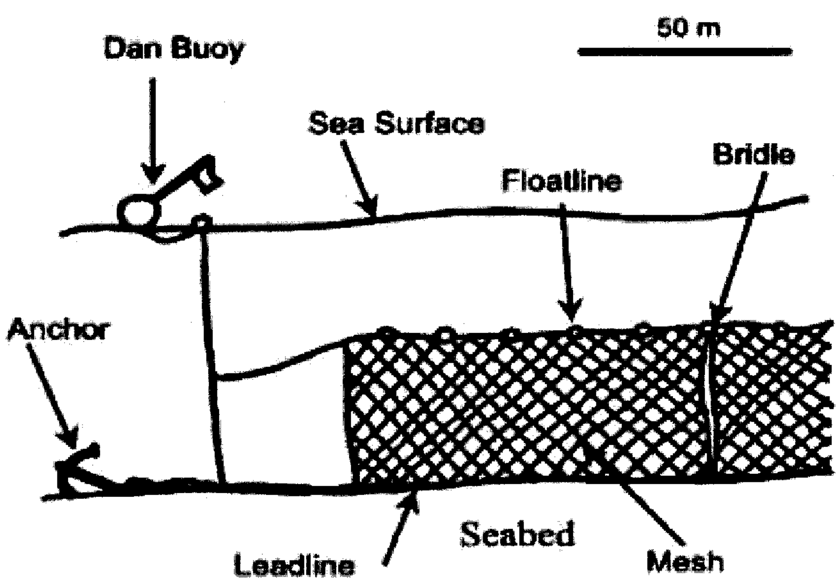

Figure 1.1. A schematic overview of a bottom-set gillnet. Adapted from Spencer *et al.* 2000.

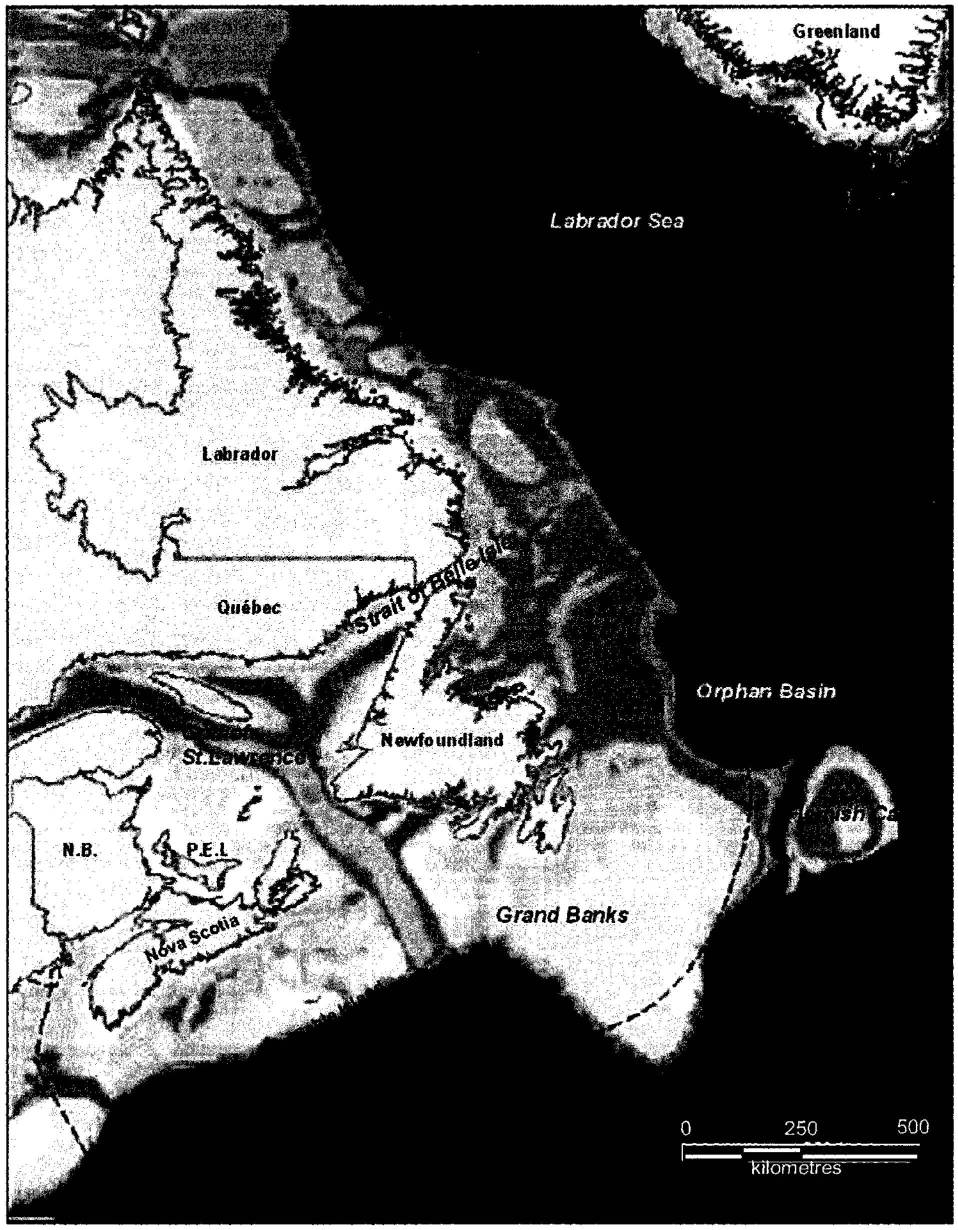

Figure 1.2: An overview of Atlantic Canadian waters. Major geographic features, as well as the 200 nm-limit of the Canadian EEZ, are indicated. Depth contour increases in 50-m increments.

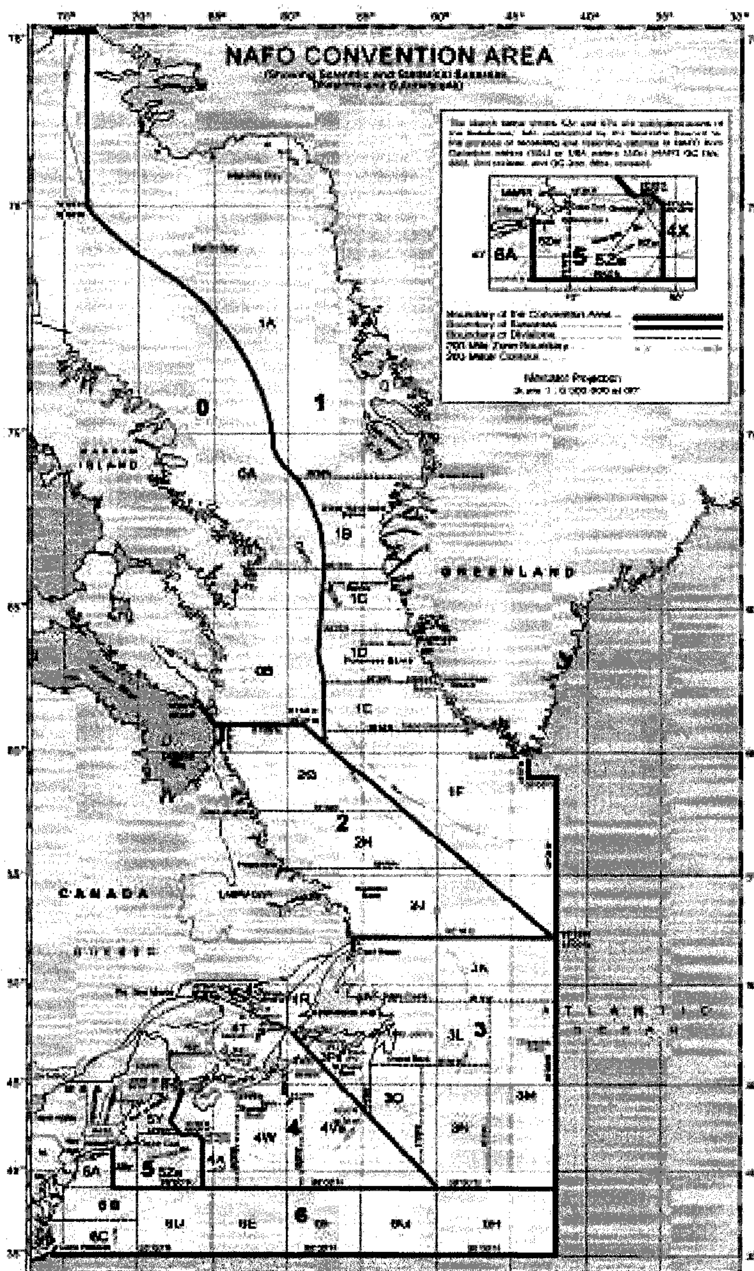

Figure 1.3: A schematic overview of the area under the mandate of the Northwest Atlantic Fisheries Organisation (NAFO), with major divisions indicated. Copyright NAFO.

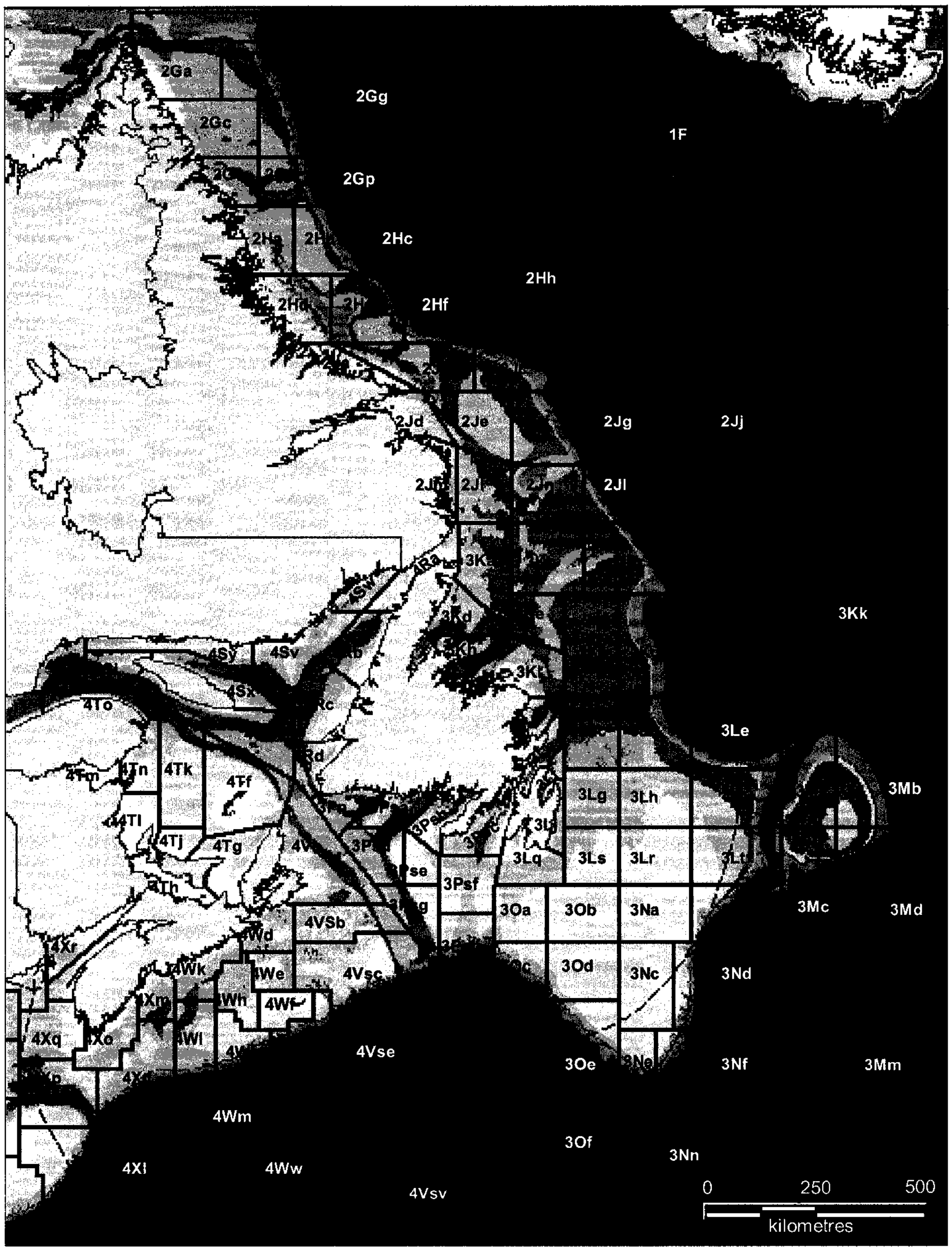

Figure 1.4: Individual NAFO units within divisions 2GHJ, 3KLMNOP and 4RSVWX, as referred to in the text. The 200 nm-limit to the Canadian EEZ is indicated by the dashed line. Depth contour increases in 50-m increments.

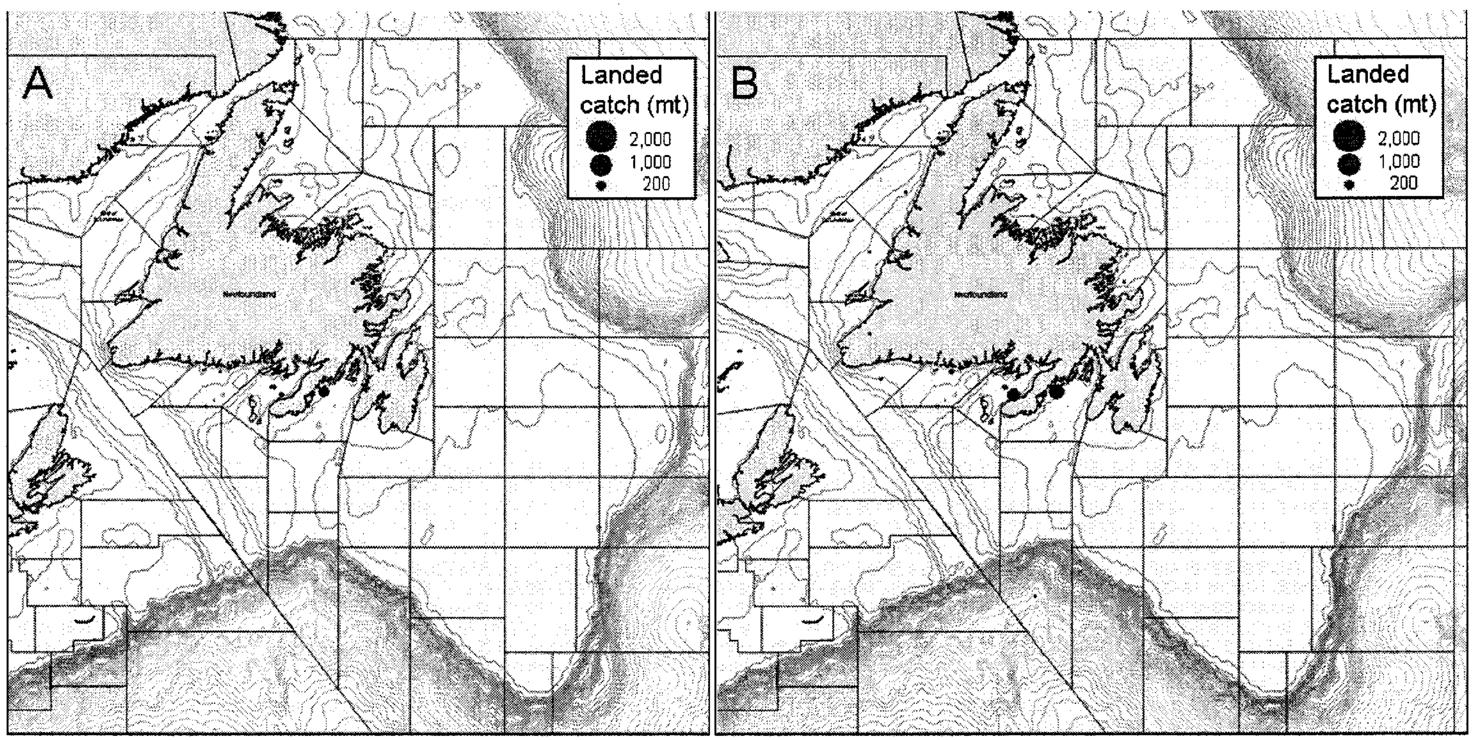

Figure 3.1 A-B. Total amount of Atlantic cod caught in the first (A) and second (B) quarter of 2002, per NAFO unit (mt round weight) . Circles represent total catches for separate NAFO units.

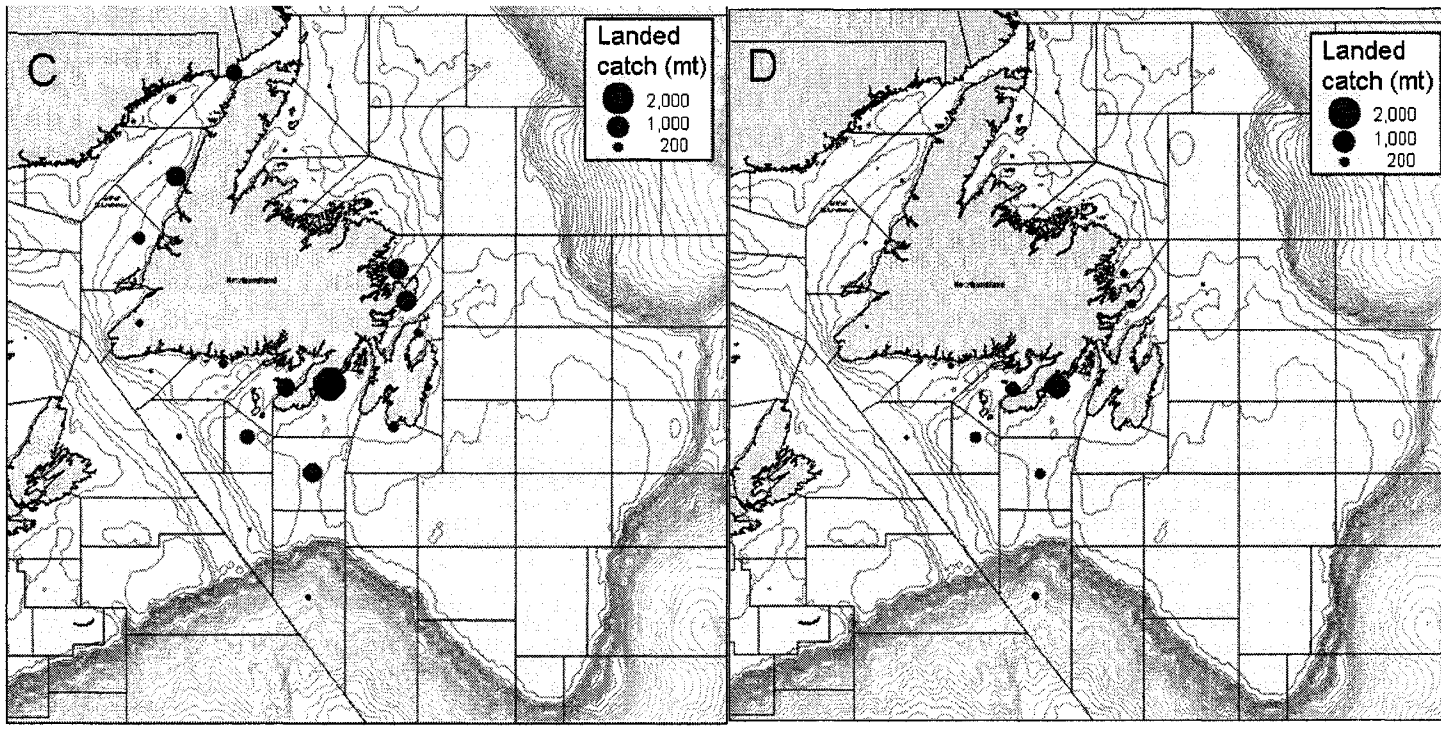

Figure 3.1 C-D. Total amount of Atlantic cod caught in the third (C) and fourth (D) quarter of 2002, per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

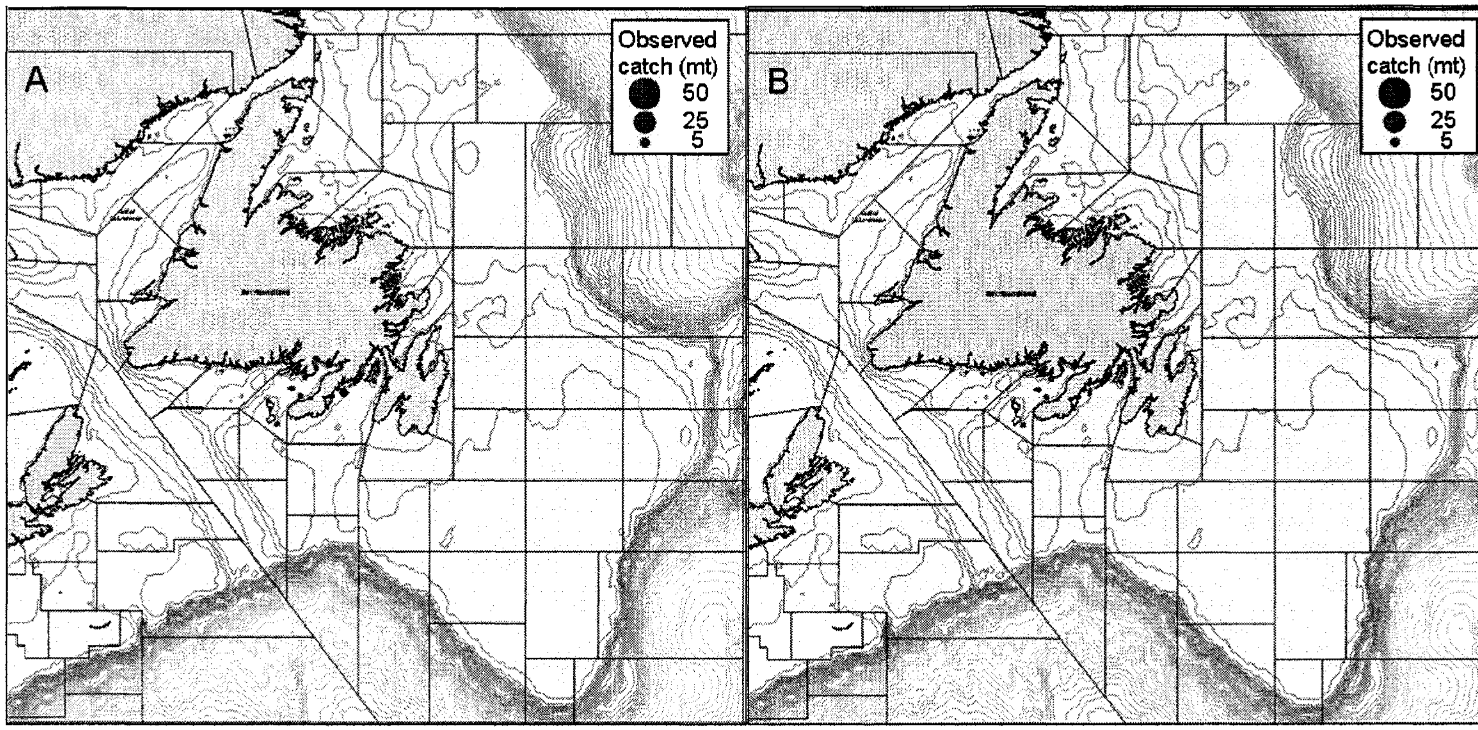

Figure 3.2 A-B. Total amount of Atlantic cod observed caught in the first (A) and second (B) quarter of 2002, per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

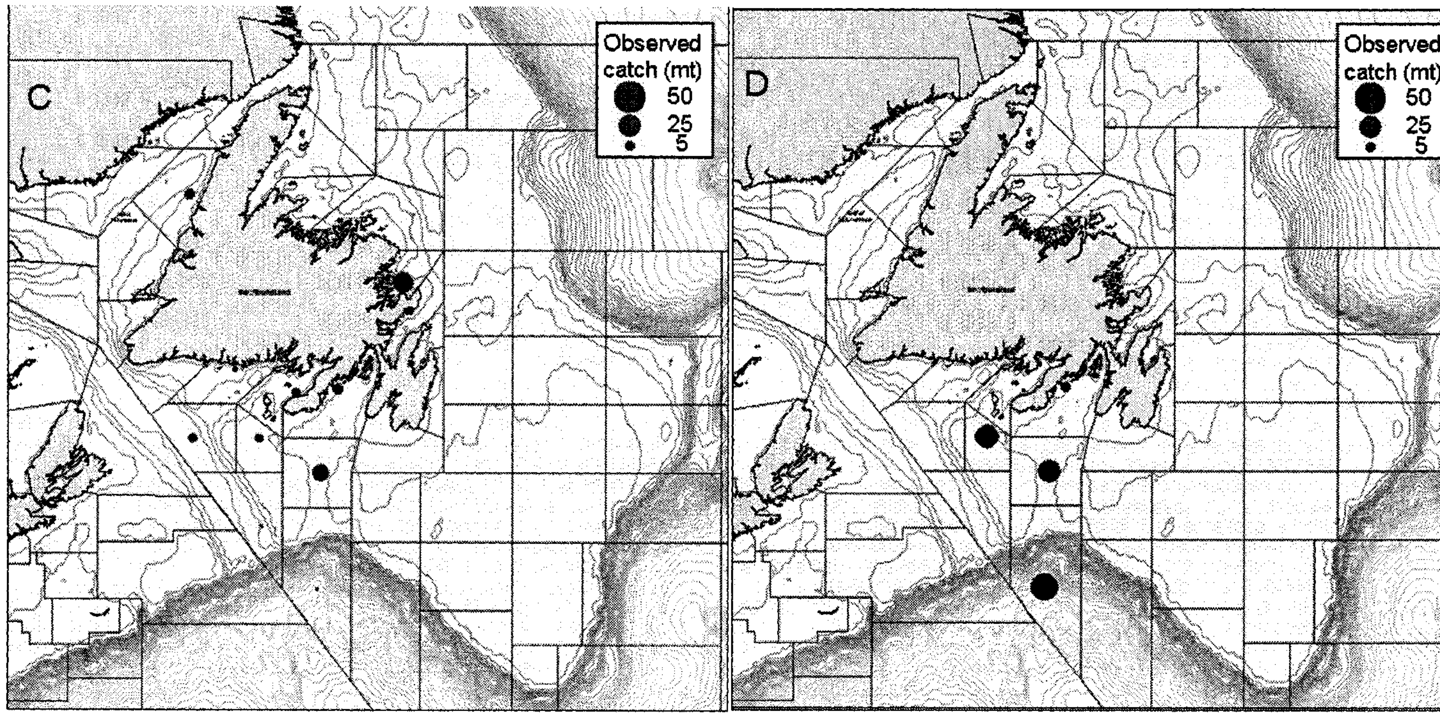

Figure 3.2 C-D. Total amount of Atlantic cod observed caught in the first (A) and second (B) quarter of 2002, per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

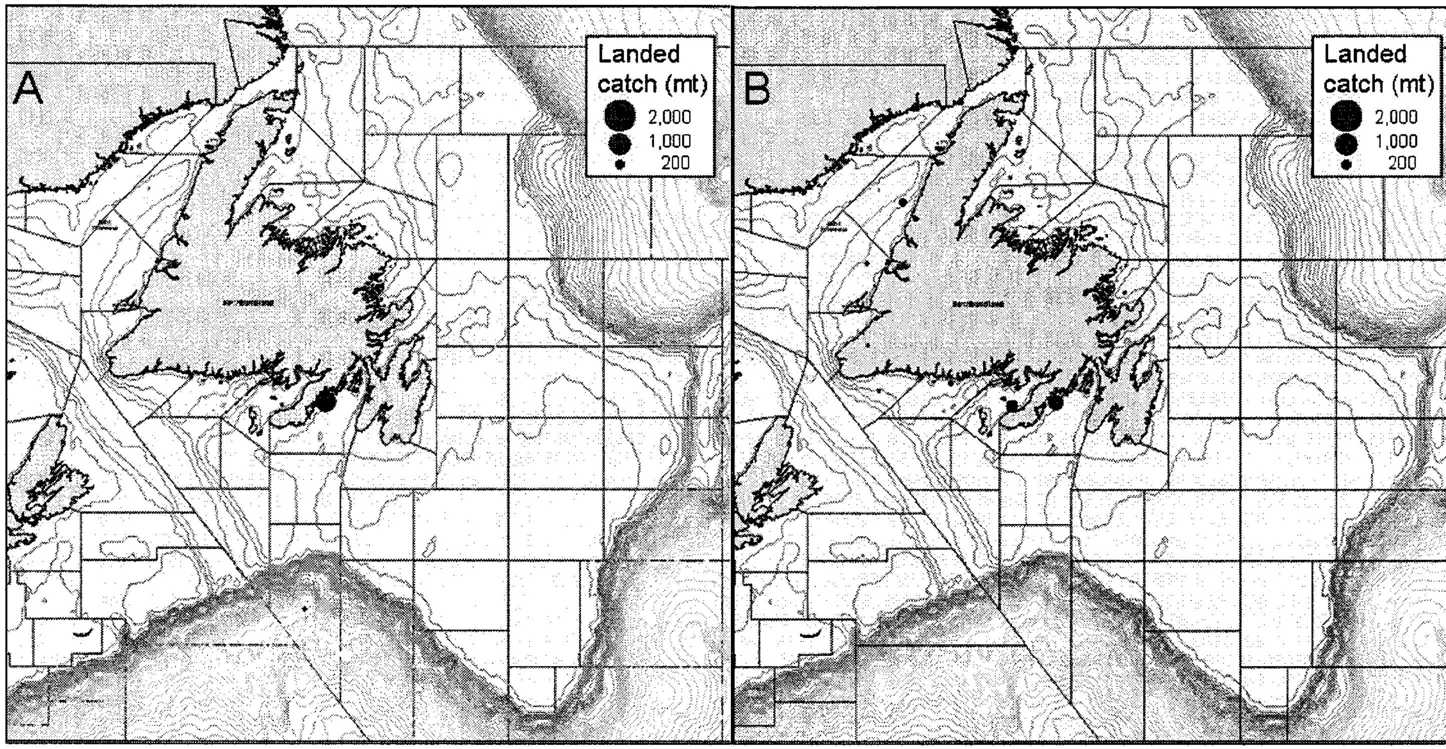

Figure 4.1 A-B. Total amount of Atlantic cod caught in the first (A) and second (B) quarter of 2001, per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

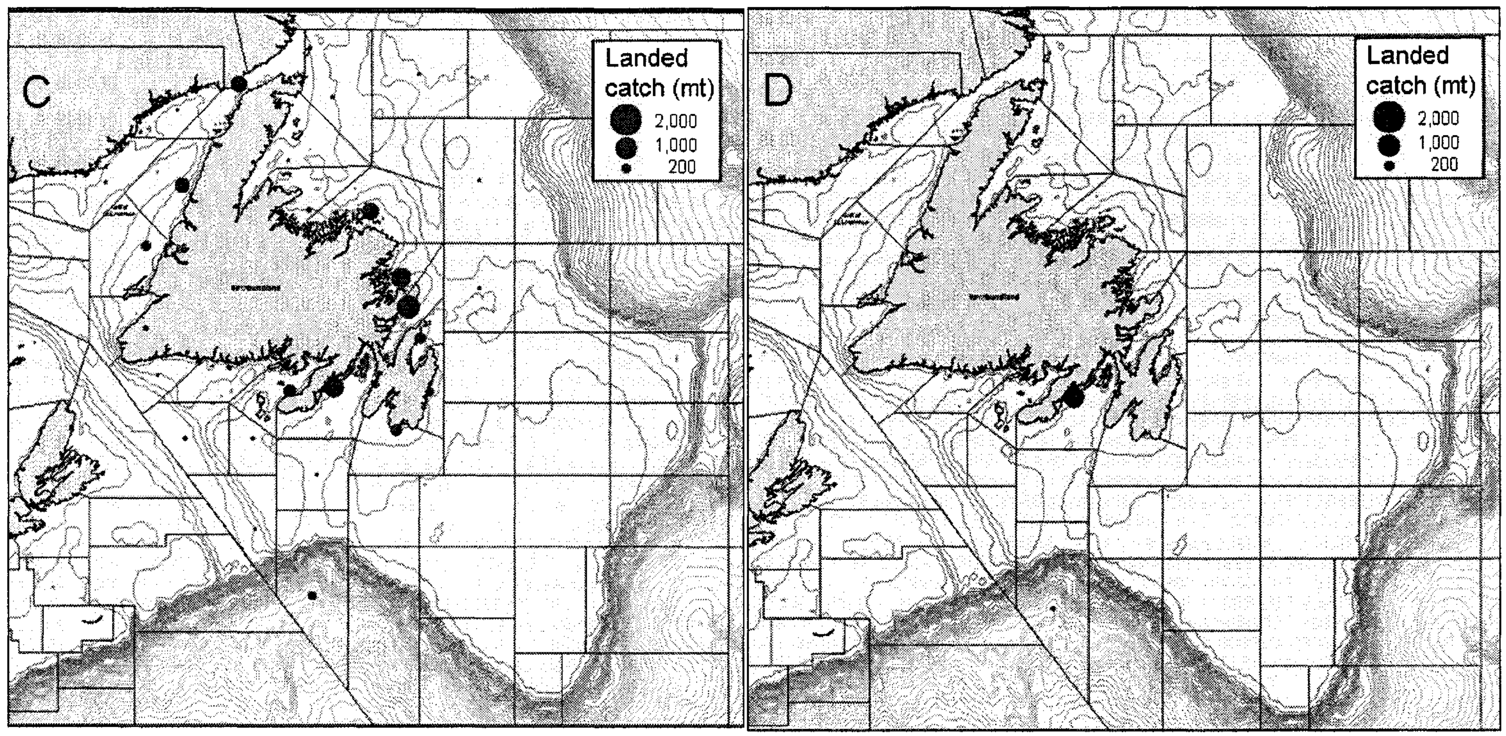

Figure 4.1 C-D. Total amount of Atlantic cod caught in the third (C) and fourth (D) quarter of 2001, per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

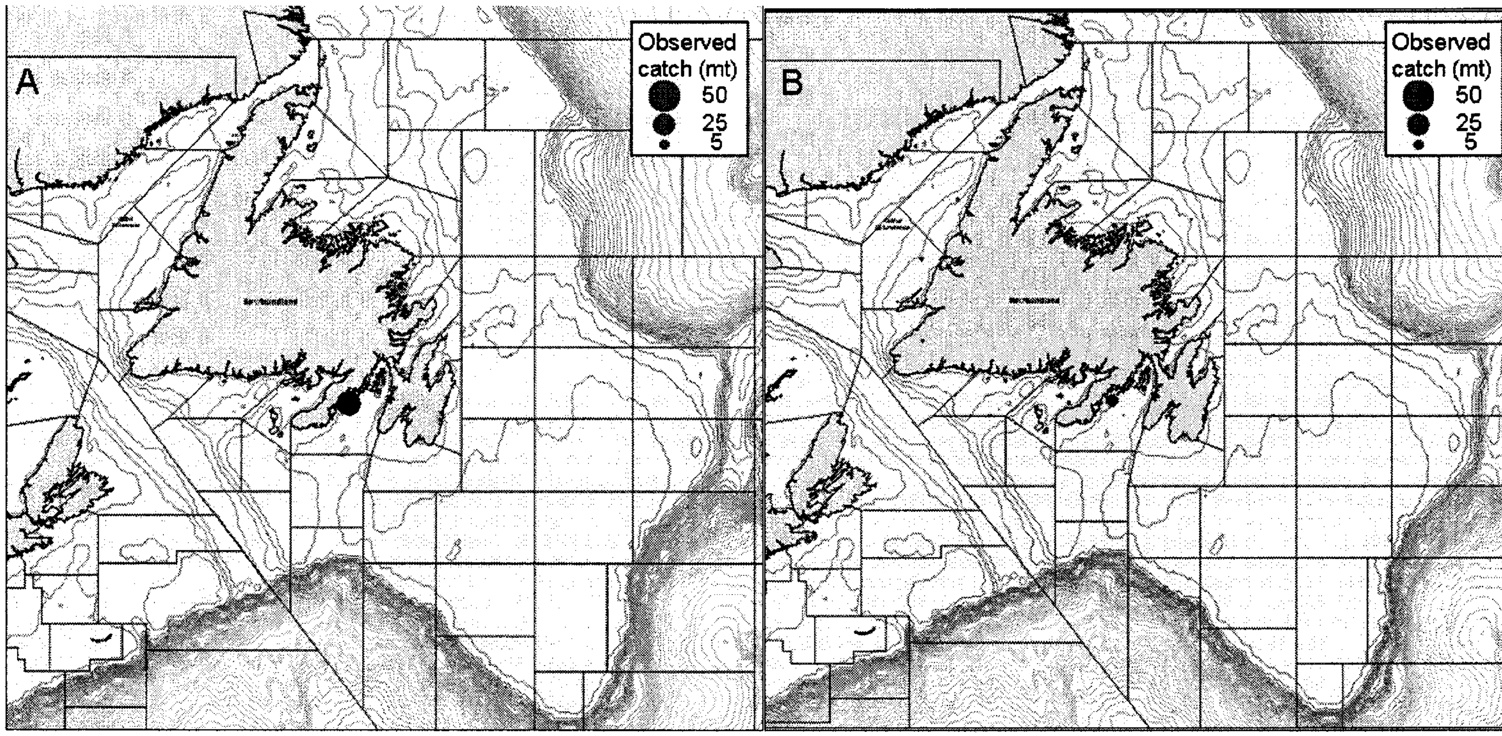

Figure 4.2 A-B. Total amount of Atlantic cod observed caught in the first (A) and second (B) quarter of 2001, per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

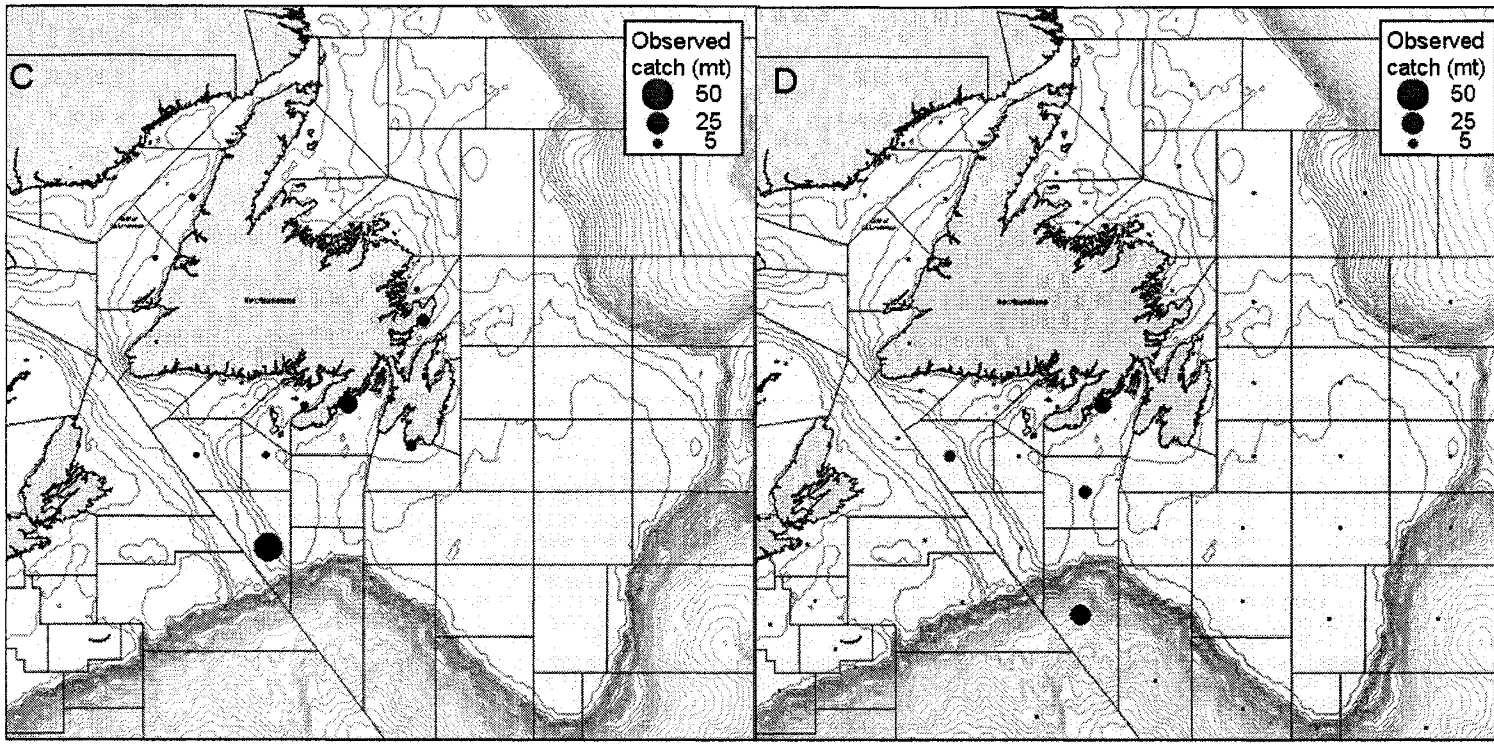

Figure 4.2 C-D. Total amount of Atlantic cod observed caught in the third (C) and fourth (D) quarter of 2001, per NAFO unit (mt round weight). Circles represent total observed catches for separate NAFO units.

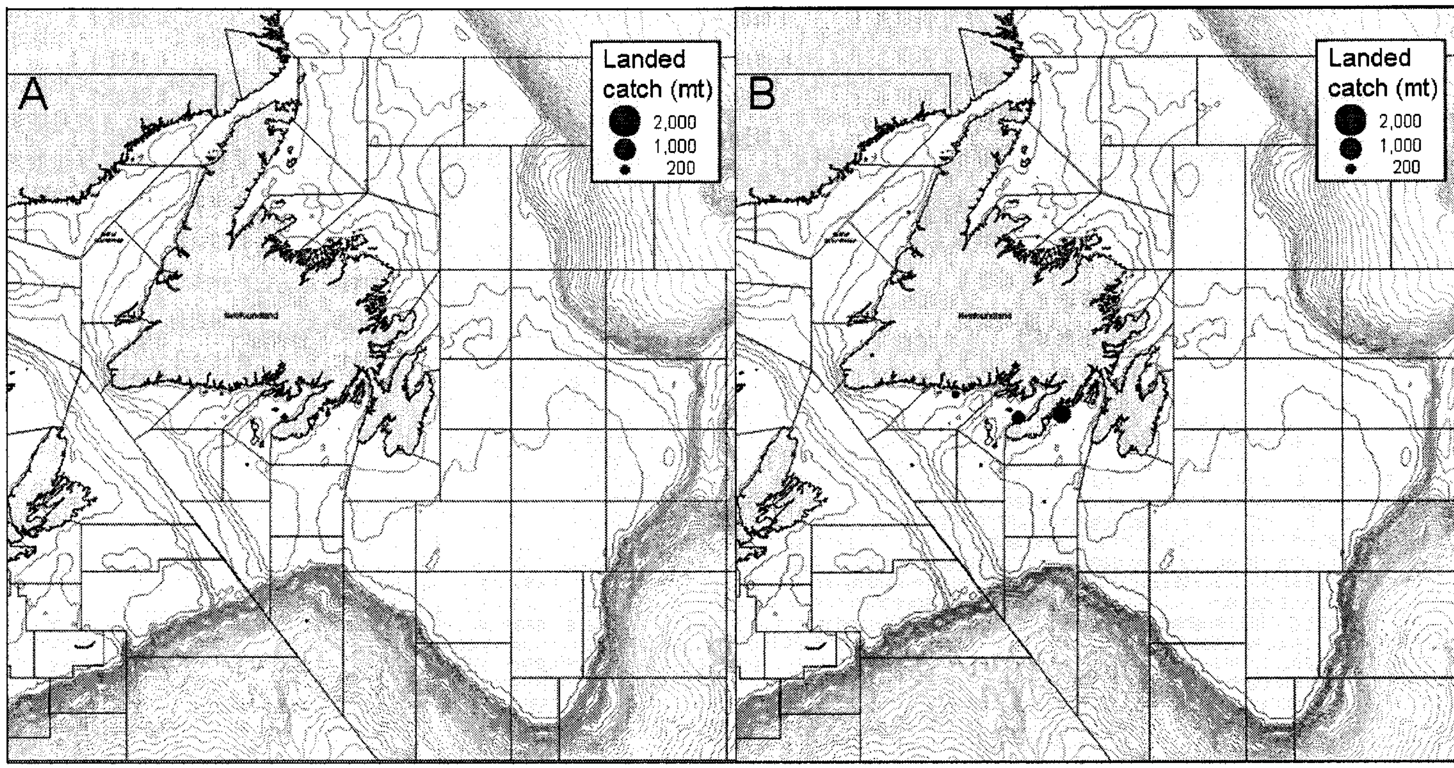

Figure 4.3 A-B. Total amount of Atlantic cod caught in the first (A) and second (B) quarter of 2003, per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

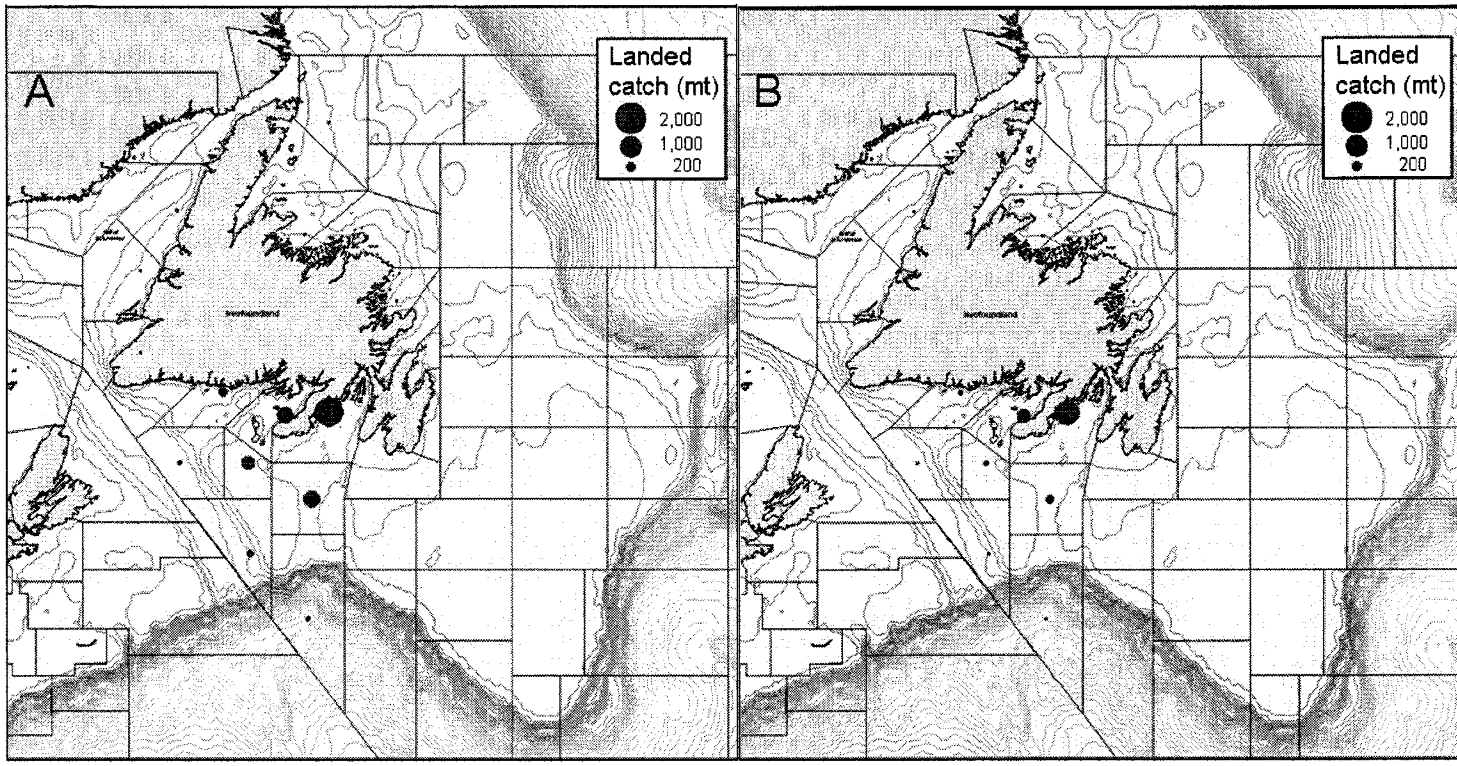

Figure 4.3 C-D. Total amount of Atlantic cod caught in the third (C) and fourth (D) quarter of 2003, per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

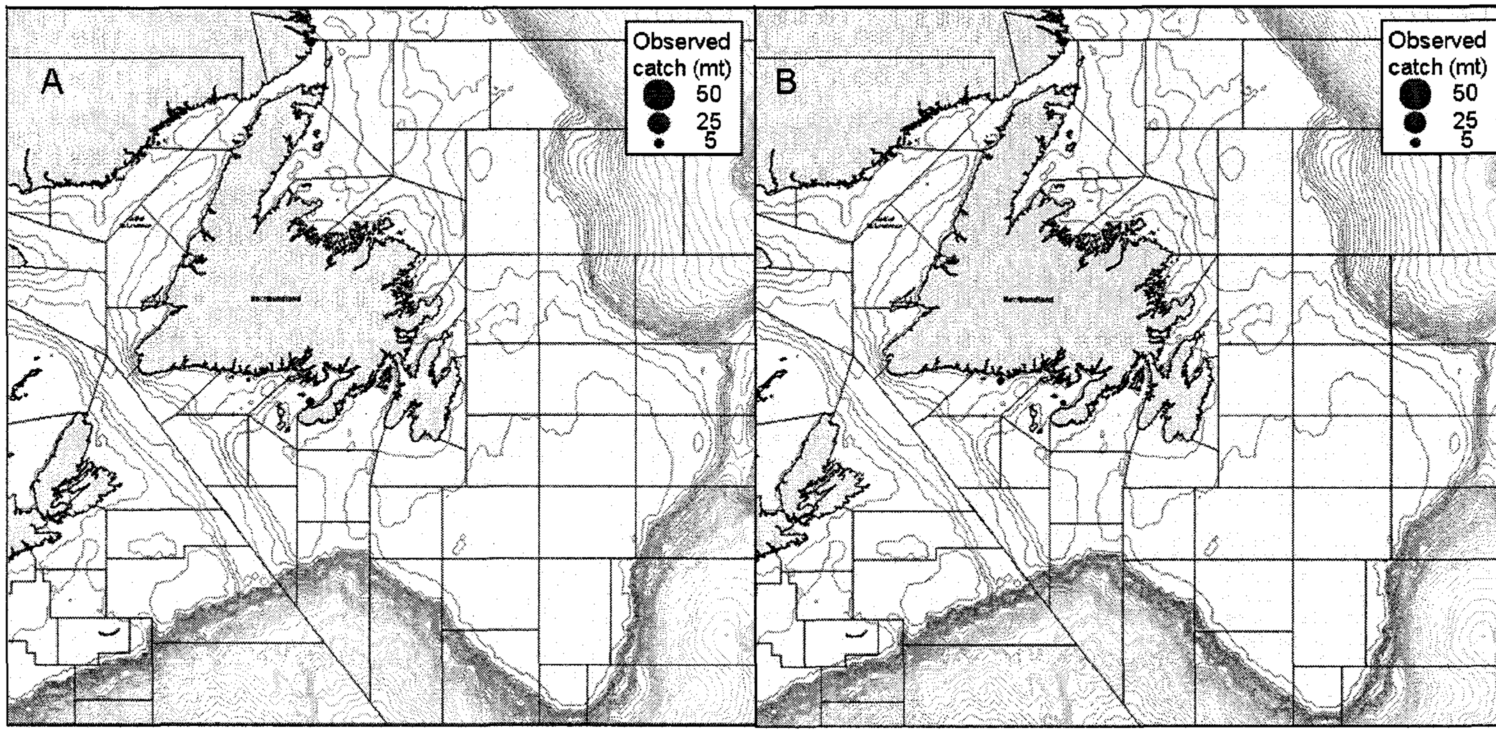

Figure 4.4 A-B. Total amount of Atlantic cod observed caught in the first (A) and second (B) quarter of 2003, per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

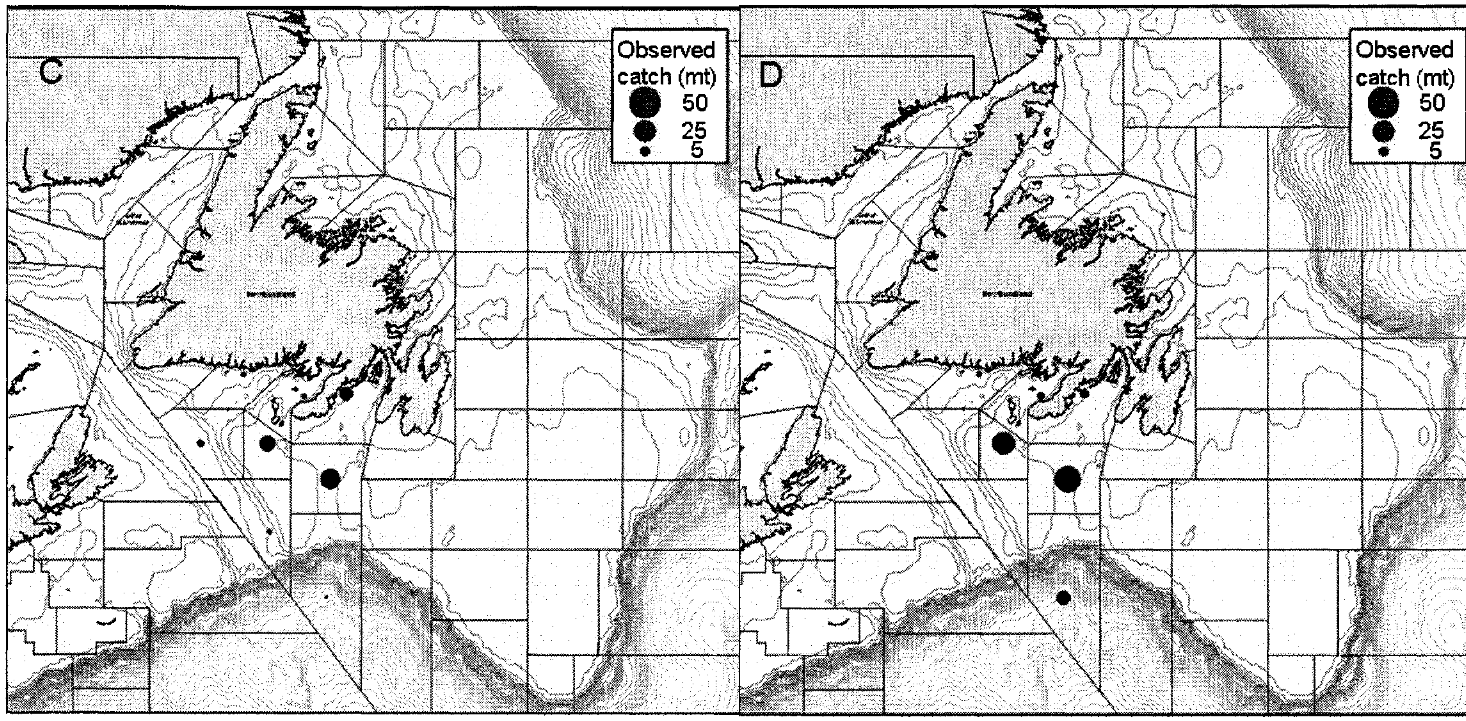

Figure 4.4 C-D. Total amount of Atlantic cod observed caught in the third (C) and fourth (D) quarter of 2003, per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

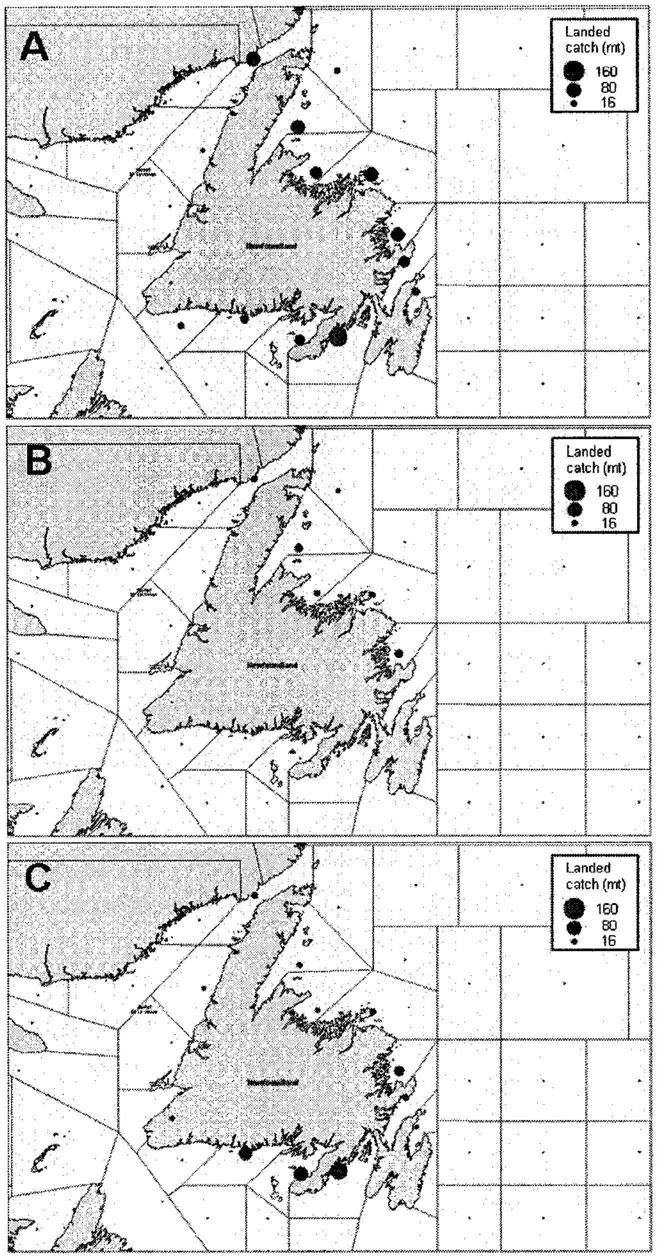

Figure 4.5 A-C. Total amounts of lumpfish caught in 2001 (A), 2002 (B) and 2003 (C), per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

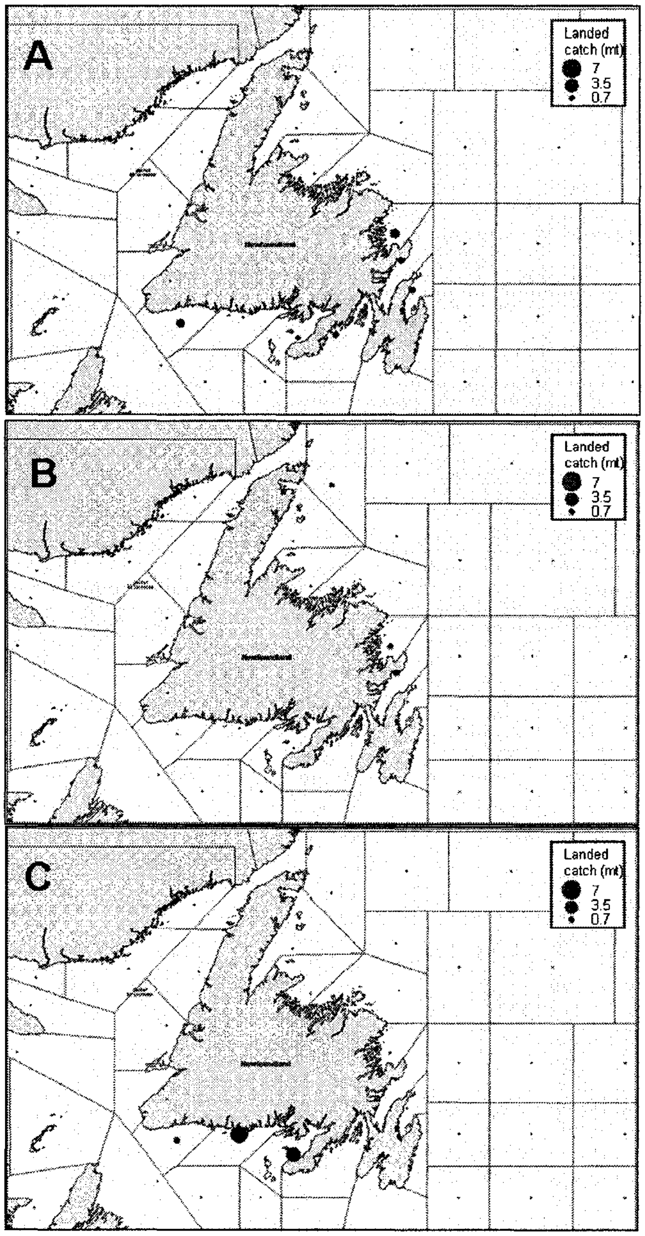

Figure 4.6 A-C. Total amounts of lumpfish observed caught in 2001 (A), 2002 (B) and 2003 (C), per NAFO unit (mt round weight). Circles represent total observed catches for separate NAFO units.

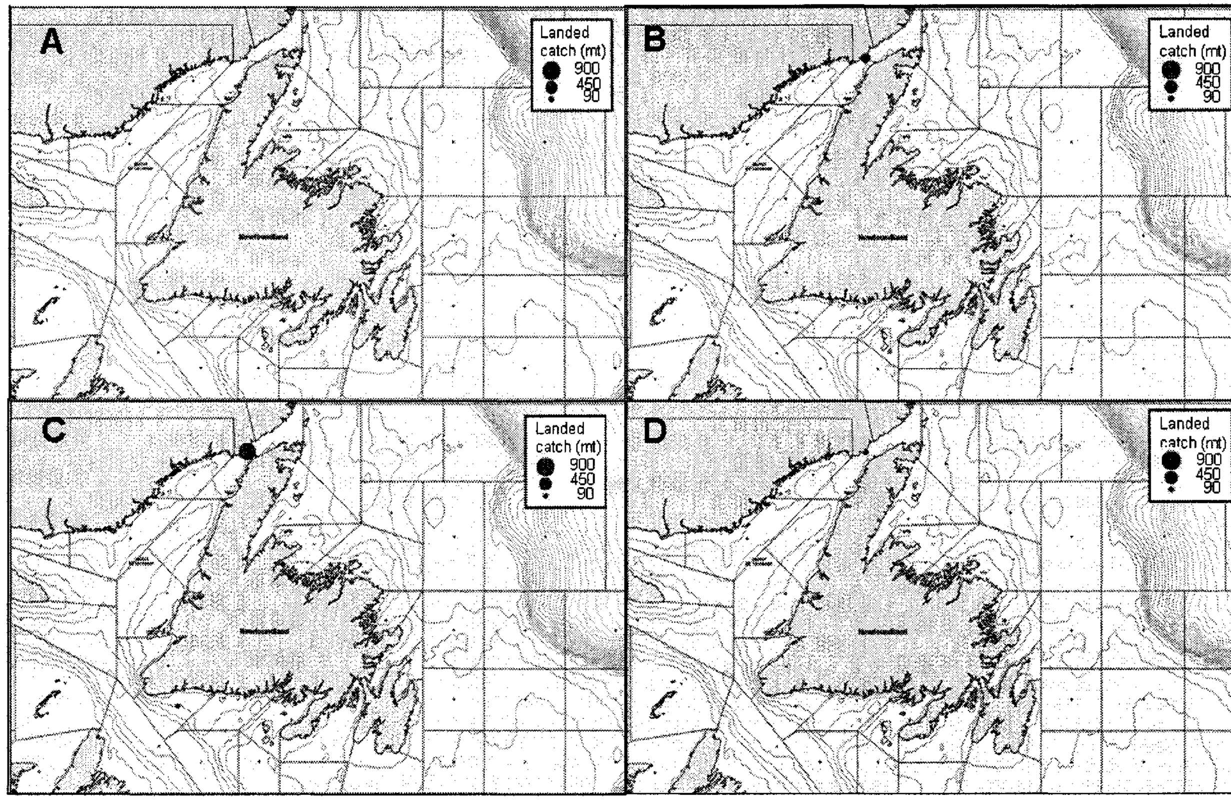

Figure 4.7 A-D. Total amounts of Atlantic herring caught in the first (A), second (B), third (C), and fourth (D) quarter of 2001, per NAFO unit (mt round weight). Circles represent total catch for separate NAFO units.

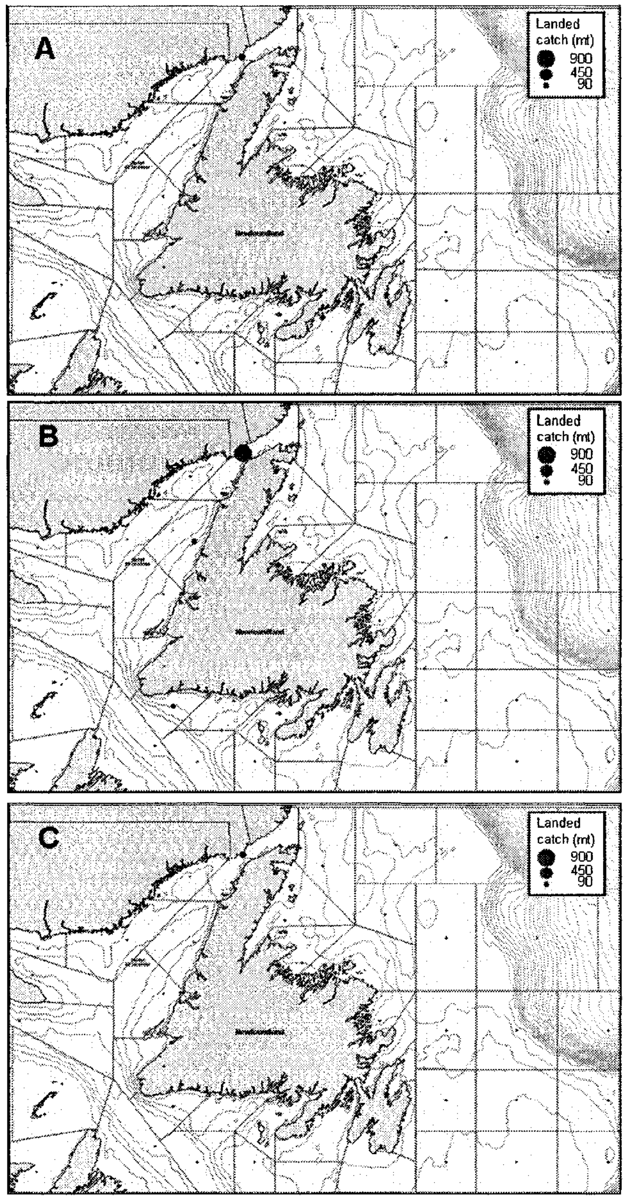

Figure 4.8 A-C. Total amounts of Atlantic herring caught in the second (A), third (B) and fourth (C) quarter of 2002, per NAFO unit (mt round weight). Circles represent total catch for separate NAFO units. No fishing effort was recorded in the first quarter of 2002.

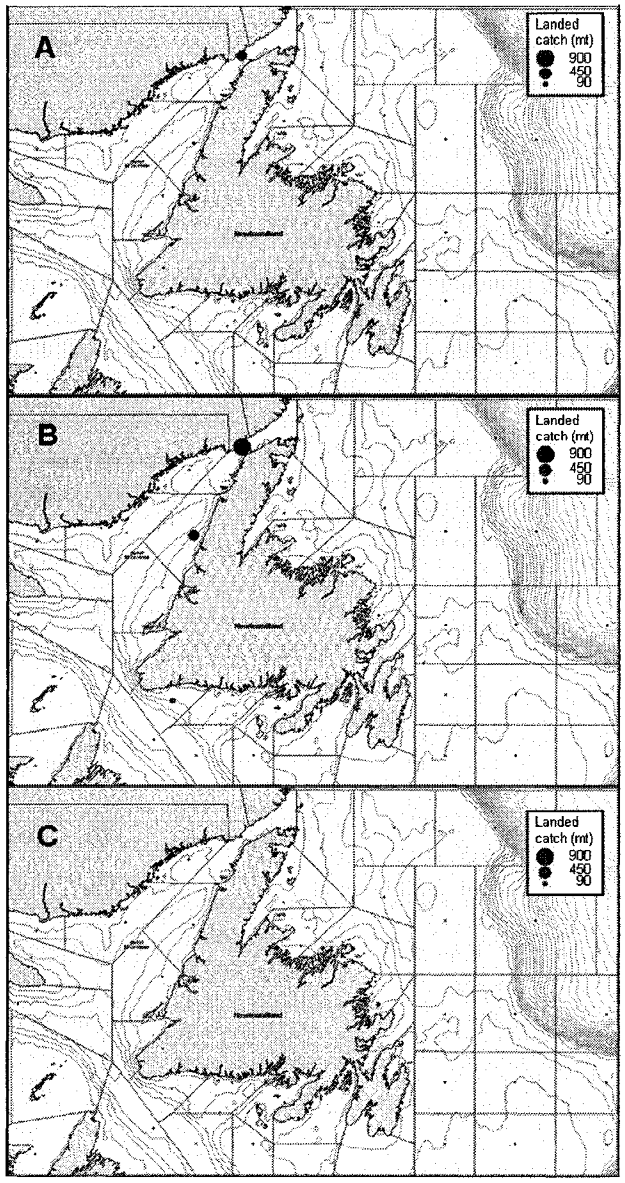

Figure 4.9 A-C. Total amounts of Atlantic herring caught in the second (A), third (B) and fourth (C) quarter of 2003, per NAFO unit (mt round weight). Circles represent total catch for separate NAFO units. No fishing effort was recorded in the first quarter of 2002.

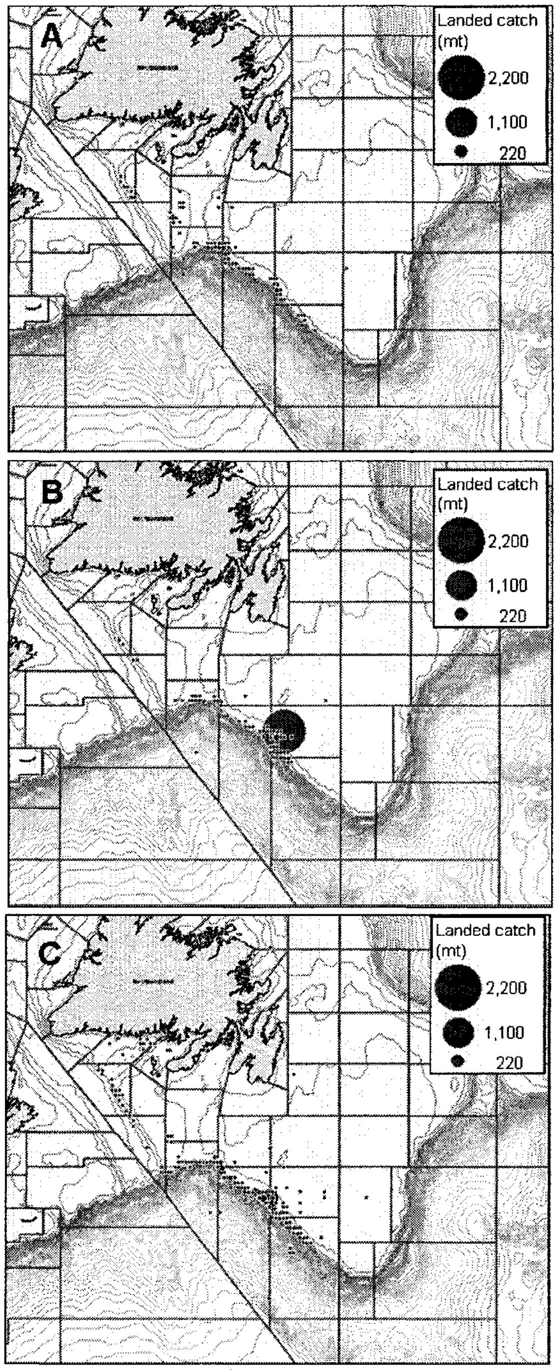

Figure 4.10 A-C. Total amounts of monkfish and skates caught in 2001 (A), 2002 (B) and 2003 (C). Circles represent total catch at the indicated coordinates (mt round weight).

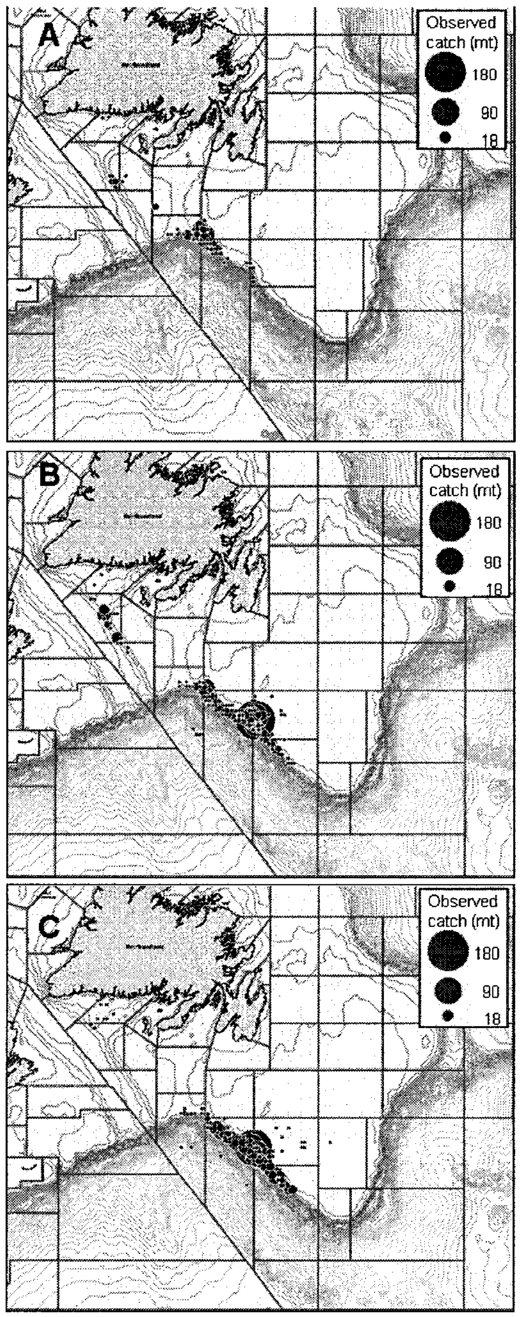

Figure 4.11 A-C. Total amounts of monkfish and skates observed caught in 2001 (A), 2002 (B) and 2003 (C). Circles represent total observed catch at the indicated coordinates (mt round weight).

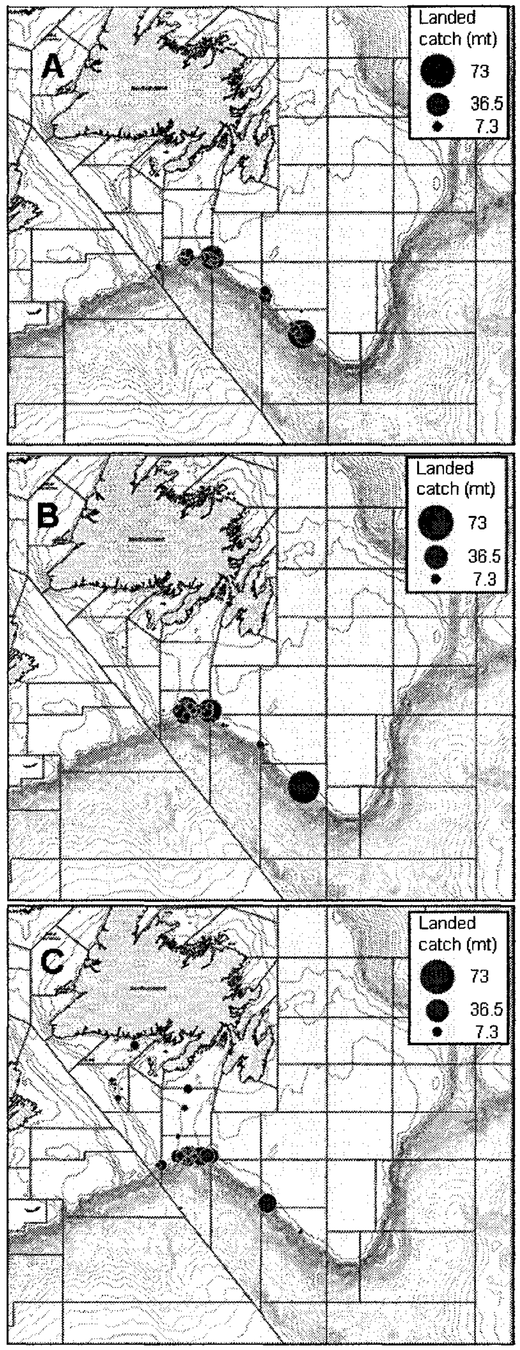

Figure 4.12 A-C. Total amounts of white hake caught in 2001 (A), 2002 (B) and 2003 (C). Circles represent total catch at the indicated coordinates (mt round weight).

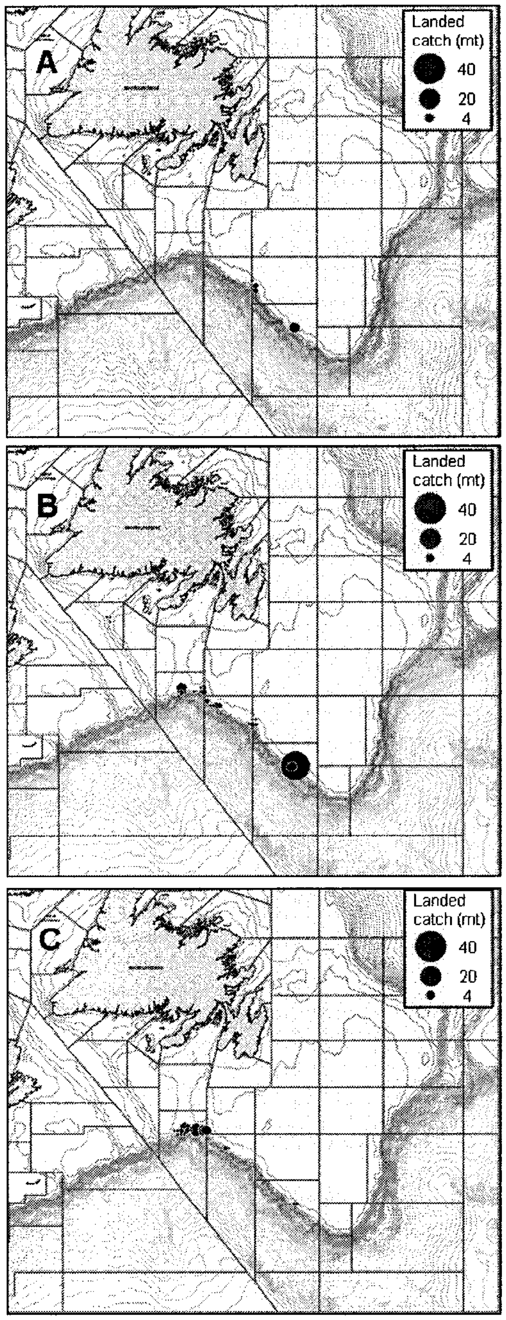

Figure 4.13 A-C. Total amounts of white hake observed caught in 2001 (A), 2002 (B) and 2003 (C). Circles represent total observed catch at the indicated coordinates (mt round weight).

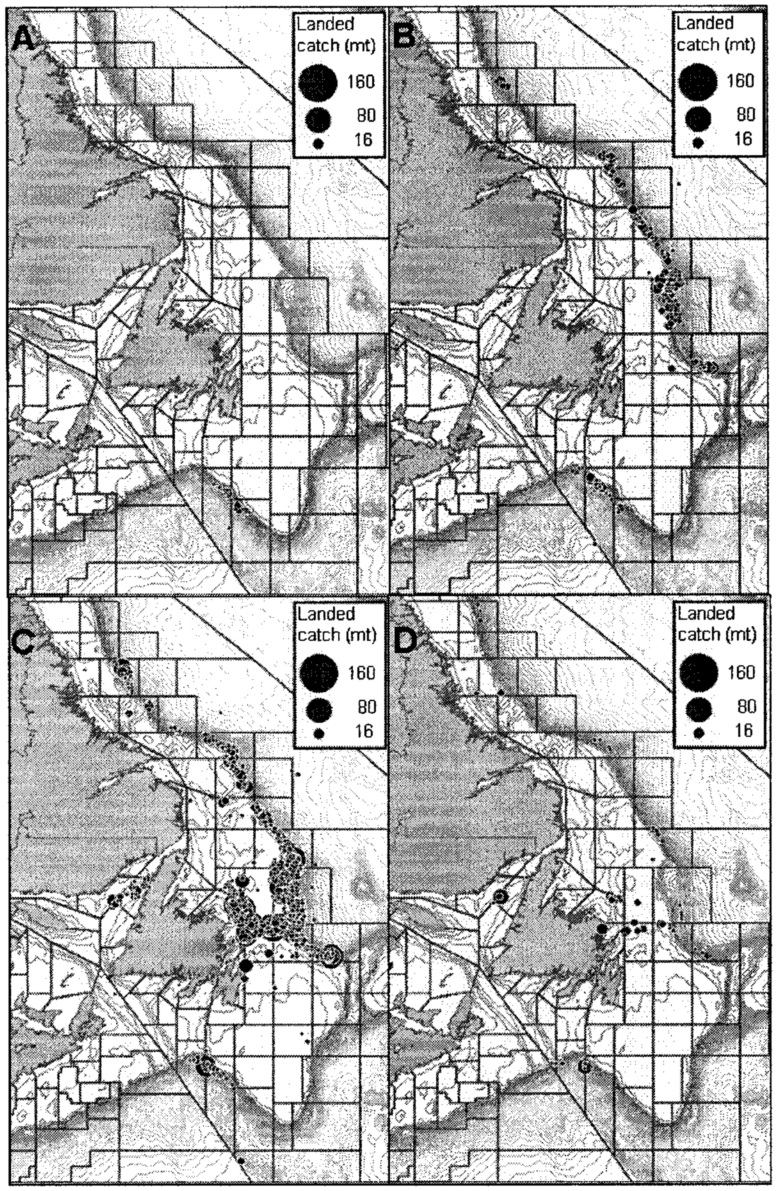

Figure 4.14 A-D. Total amounts of Greenland halibut caught in the first (A), second (B), third (C) and fourth (D) quarter of 2001. Circles represent total catch at the indicated coordinates (mt round weight).

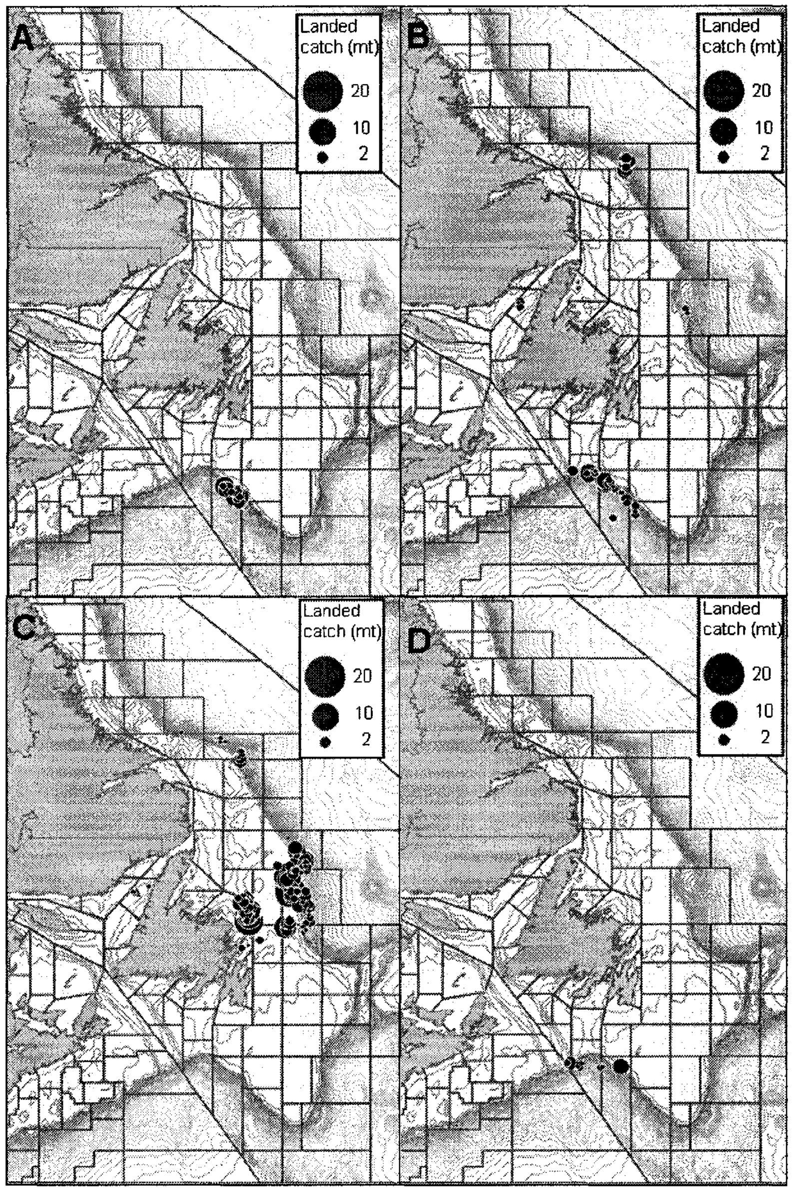

Figure 4.15 A-D. Total amounts of Greenland halibut observed caught in the first (A), second (B), third (C) and fourth (D) quarter of 2001. Circles represent total observed catch at the indicated coordinates (mt round weight).

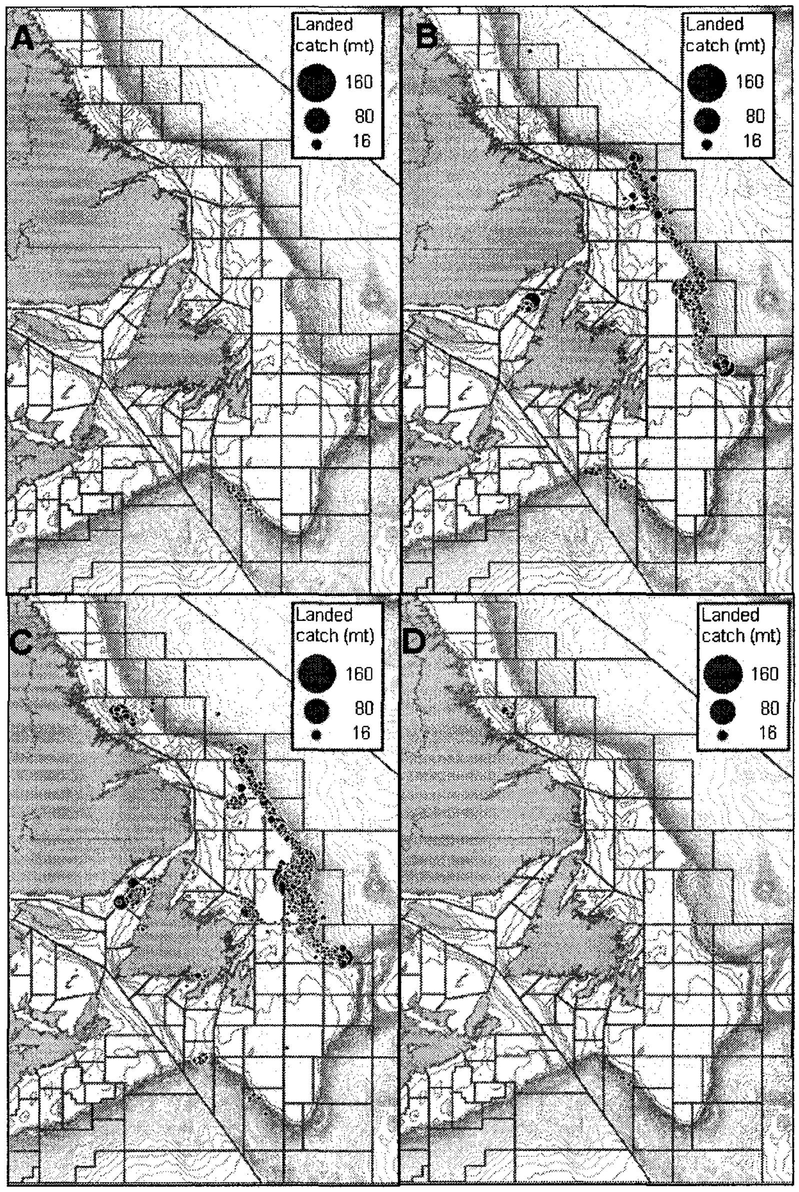

Figure 4.16 A-D. Total amounts of Greenland halibut caught in the first (A), second (B), third (C) and fourth (D) quarter of 2002. Circles represent total catch at the indicated coordinates (mt round weight).

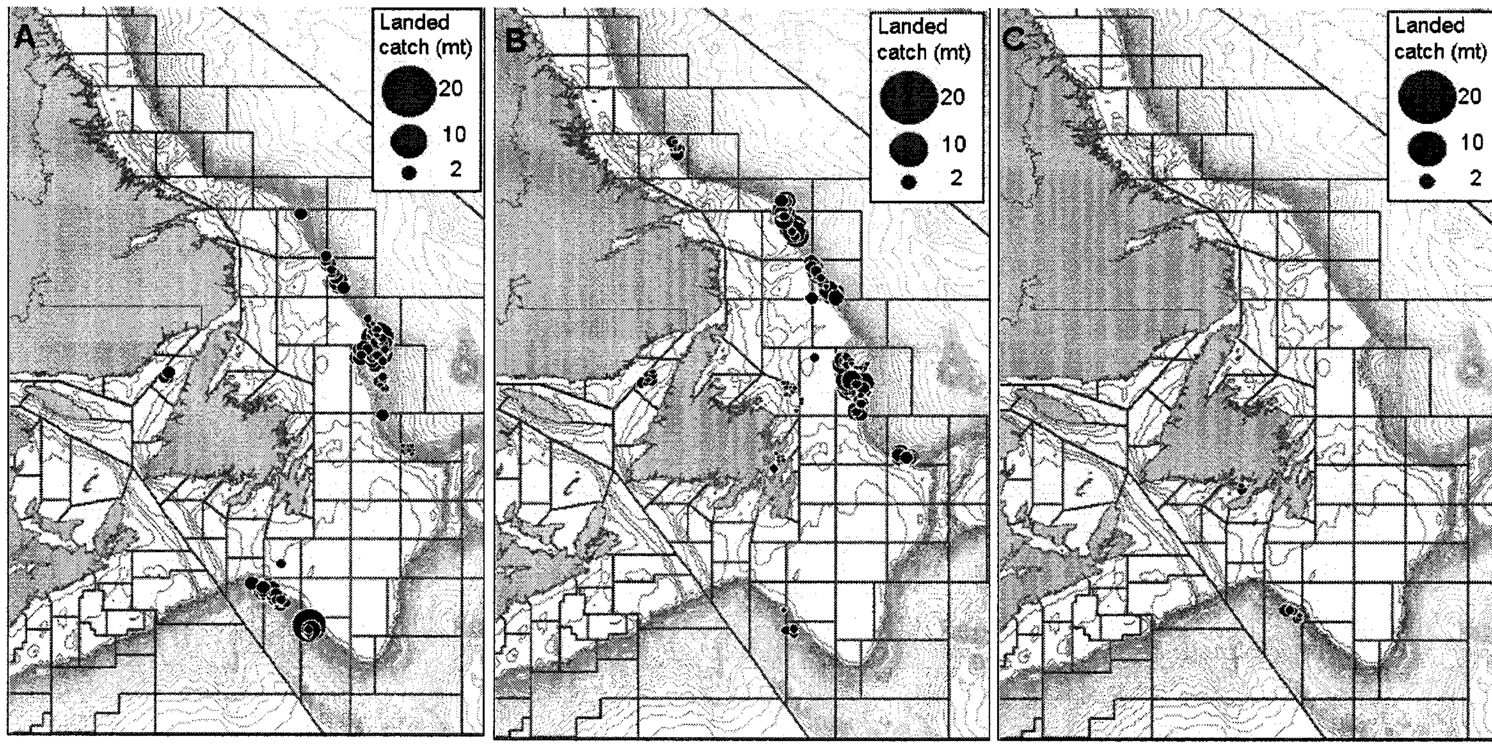

Figure 4.17 A-C. Total amounts of Greenland halibut observed caught in the second (A), third (B) and fourth (C) quarter of 2002. Circles represent total observed catch at the indicated coordinates (mt round weight). No fishing effort was observed in the first quarter of 2002.

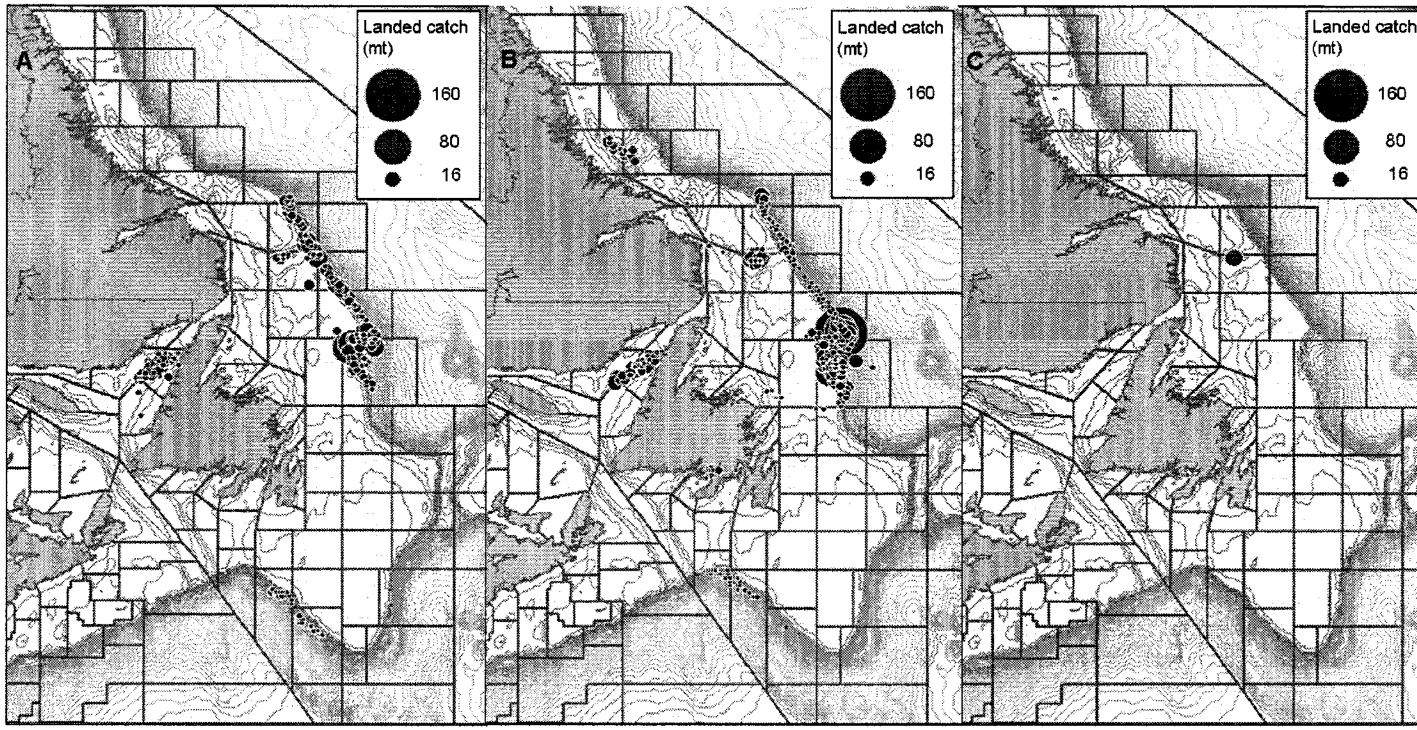

Figure 4.18 A-C. Total amounts of Greenland halibut caught in the second (A), third (B) and fourth (C) quarter of 2003. Circles represent total catch at the indicated coordinates (mt round weight). No fishing effort was recorded in the first quarter of 2003.

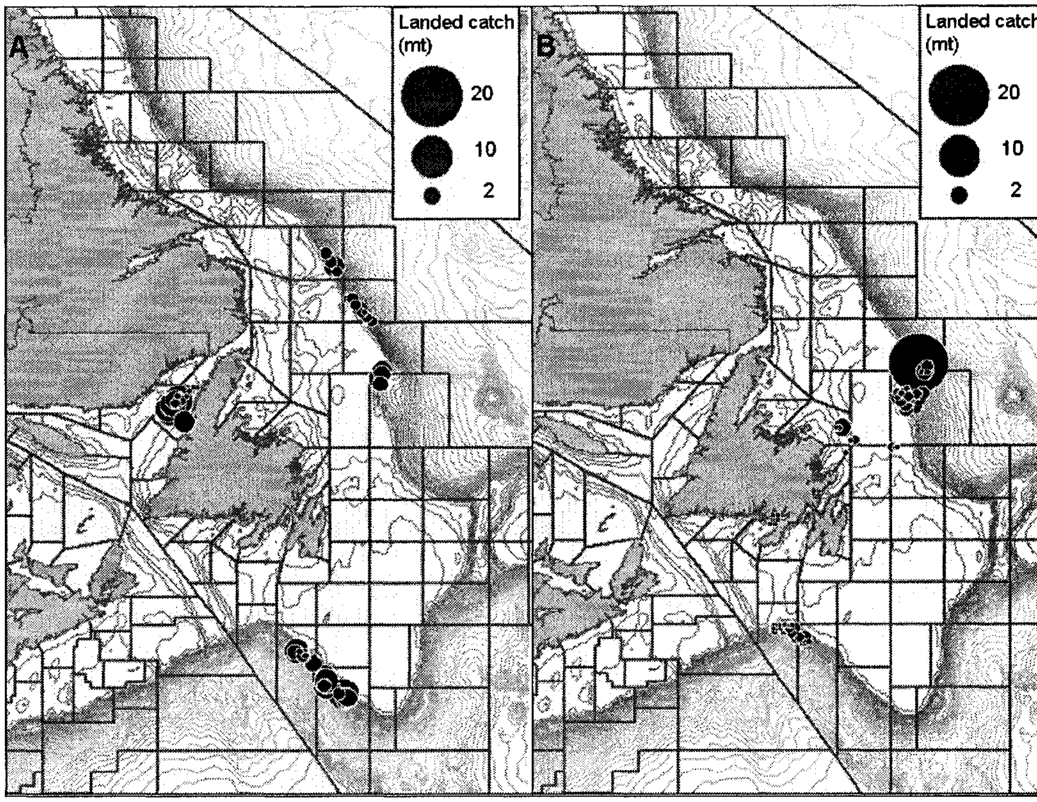

Figure 4.19 A-B. Total amounts of Greenland halibut observed caught in the second (A) and third (B) quarter of 2003. Circles represent total observed catch at the indicated coordinates (mt round weight). No fishing effort was observed in the first and fourth quarter of 2003.

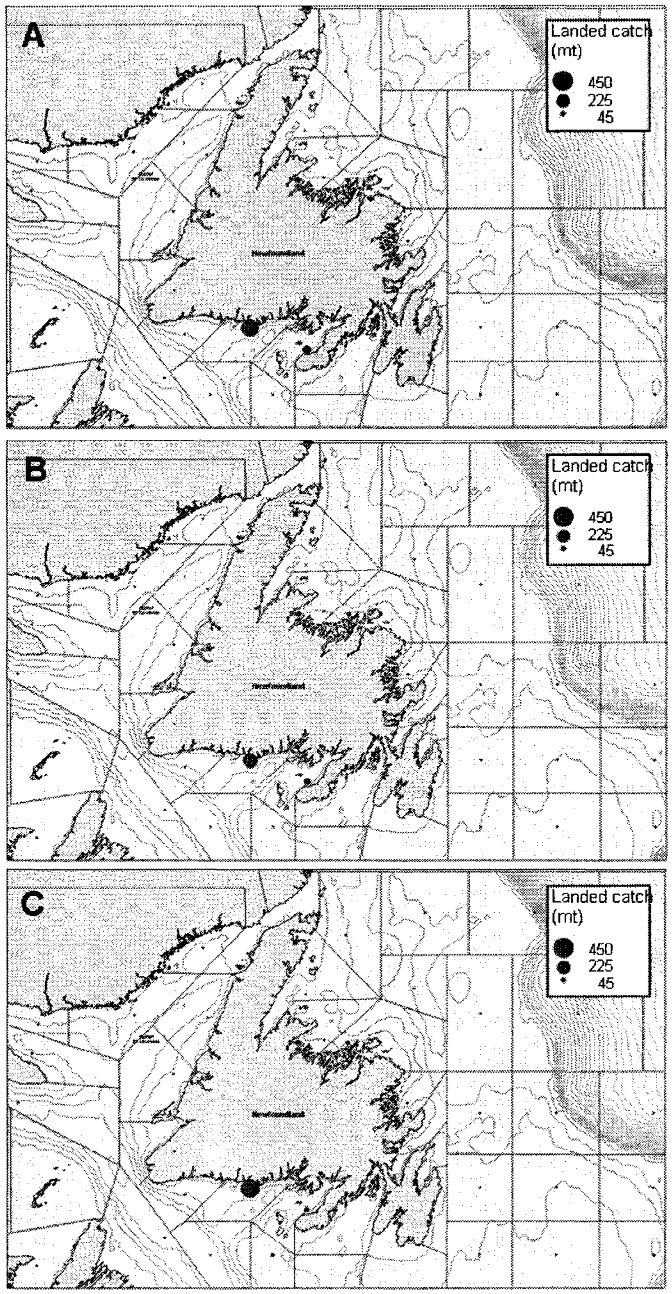

Figure 4.20 A-C. Total amounts of redfish caught in 2001 (A), 2002 (B) and 2003 (C), per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

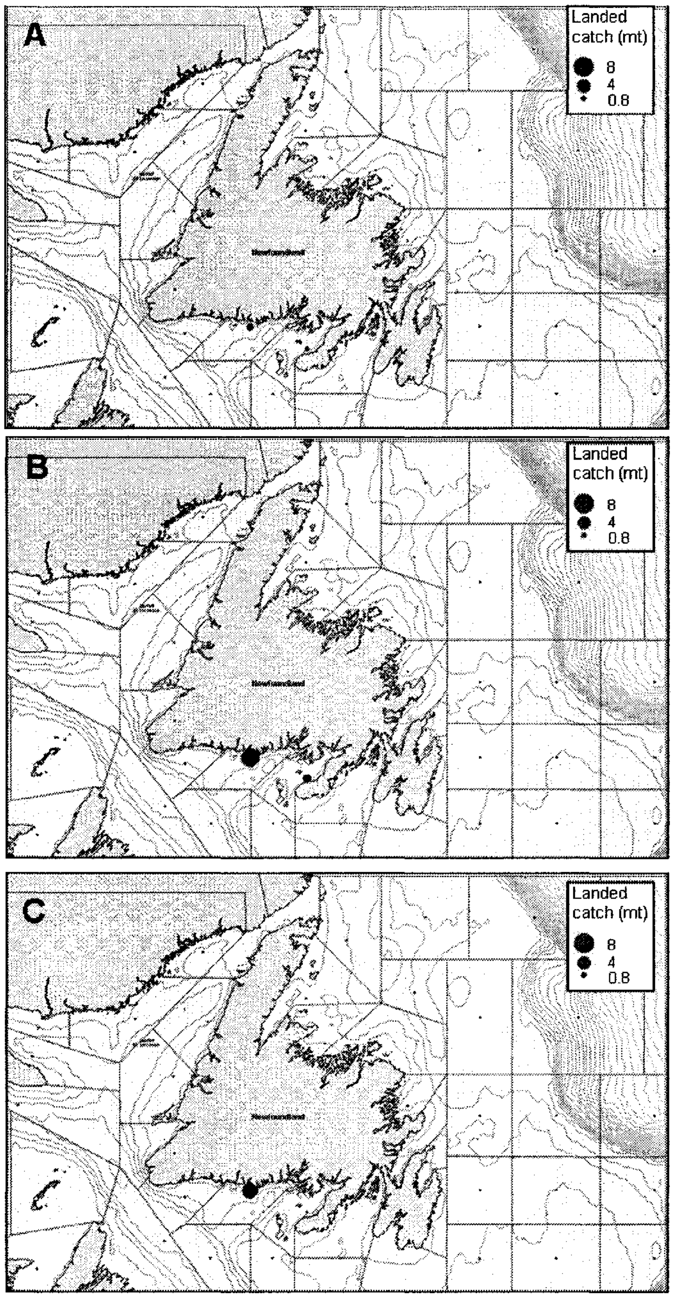

Figure 4.21 A-C. Total amounts of redfish observed caught in 2001 (A), 2002 (B) and 2003 (C), per NAFO unit (mt round weight). Circles represent total observed catches for separate NAFO units.

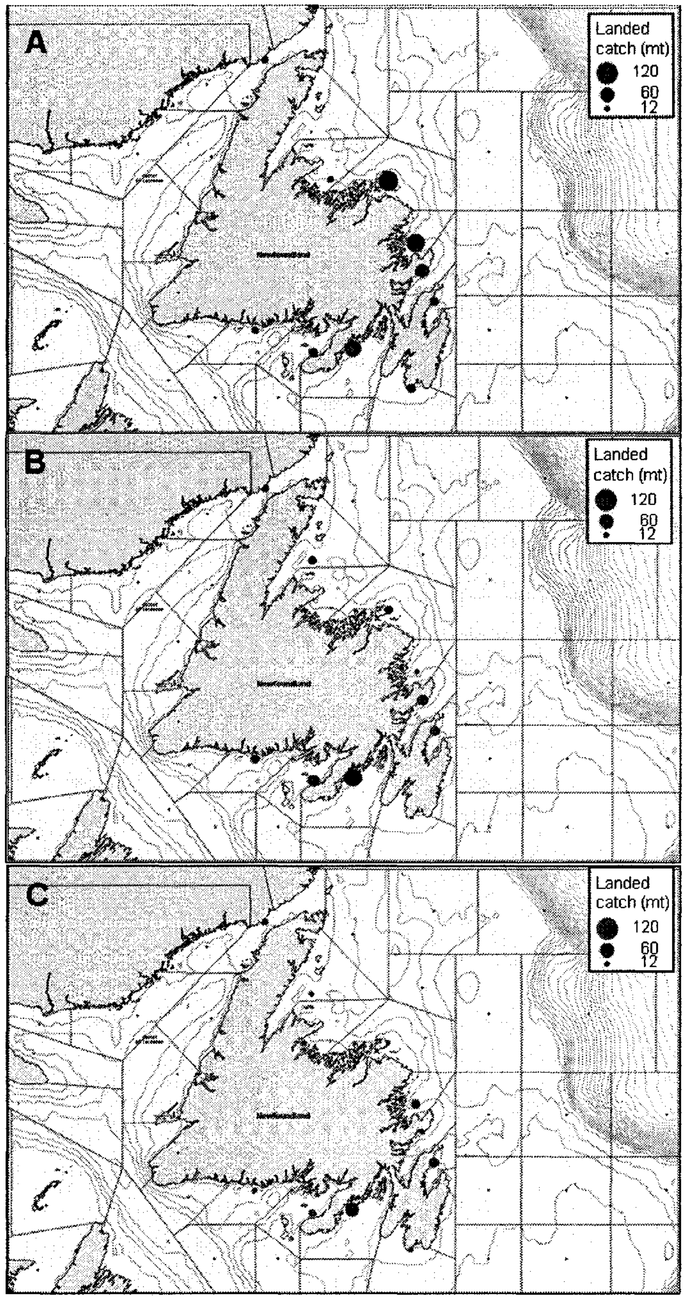

Figure 4.22 A-C. Total amounts of winter flounder caught in 2001 (A), 2002 (B) and 2003 (C), per NAFO unit (mt round weight). Circles represent total catches for separate NAFO units.

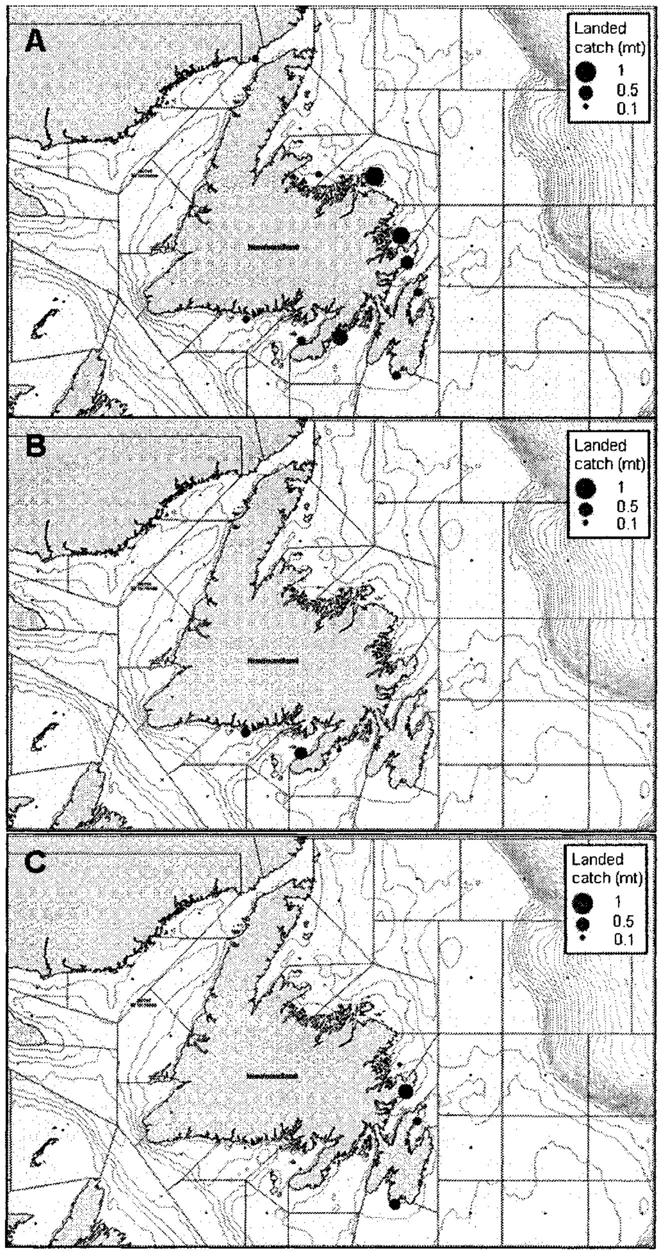

Figure 4.23 A-C. Total amount of winter flounder observed caught in 2001 (A), 2002 (B) and 2003 (C), per NAFO unit (mt round weight). Circles represent total observed catches for separate NAFO units.

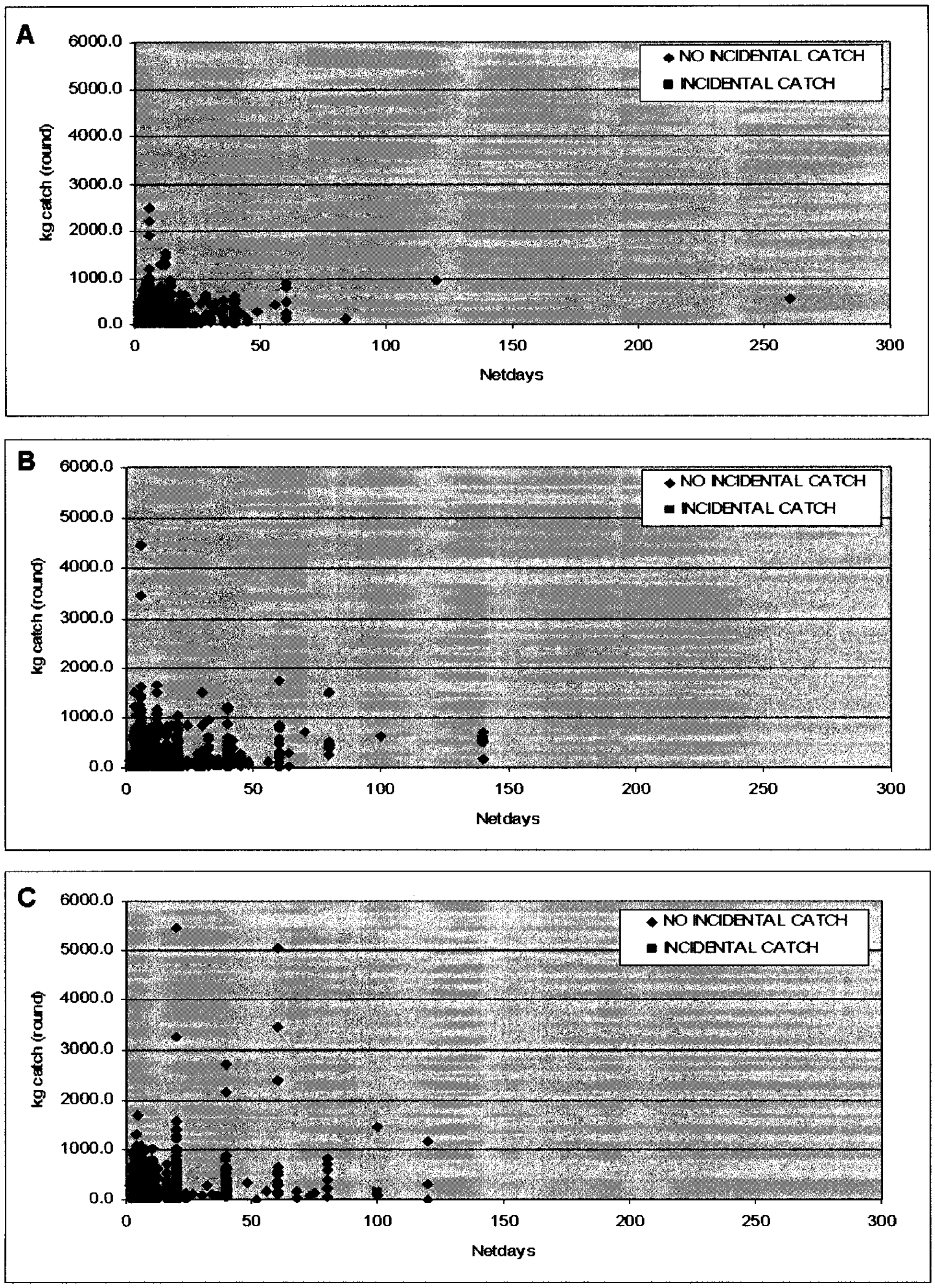

Figure 4.24 A-C. Weight of Atlantic cod caught (kg round weight) plotted as a function of the number of netdays in each individual trip, for fishers with and without small cetacean incidental catch, in 2001 (A), 2002 (B) and 2003 (C).

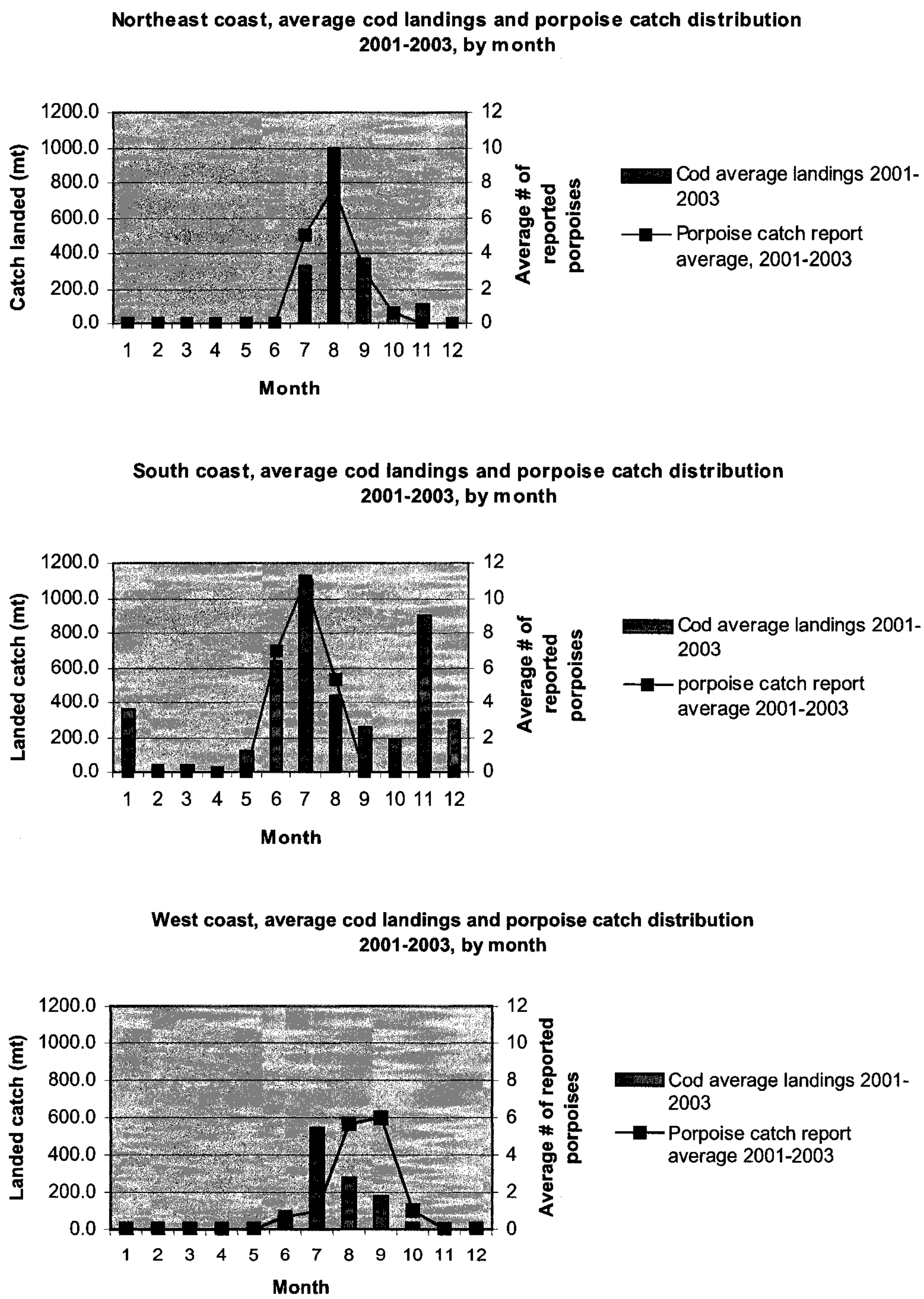

Figure 4.25: Monthly average landed catch of cod (mt round weight) and average number of reports of incidentally caught harbour porpoises, for 2001-2003, per coastline.