Recent harbour porpoise bycatch in gillnet fisheries in Newfoundland and Labrador, Canada

STEVEN BENJAMINS*, JACK LAWSON+ AND GARRY STENSON+

Contact e-mail: stevenbenjamins@yahoo.com

ABSTRACT

Despite reduced fishing effort in many North Atlantic fisheries following collapse of fish stocks, concerns remain about levels of direct mortality of harbour porpoise (*Phocoena phocoena*), primarily through incidental catches in fishing gear. Although harbour porpoise incidental catch is known to occur in several fisheries along the coast of Newfoundland and Labrador, Canada, there are no reliable quantitative estimates for the last decade when the commercial fisheries have undergone major changes in effort and target species. Based on incidental catch rates derived using different reporting methods, with net-days as measures of effort and fishing trips as sampling units, the potential number of incidental catches of harbour porpoises in several gillnet fisheries in Newfoundland waters was estimated for the years 2001, 2002 and 2003. Confidence intervals were calculated using re-sampling techniques.

Incidental catches of small cetaceans were estimated to be 862 in 2001, 1,428 in 2002 and 2,228 in 2003 in Newfoundland gillnet fisheries; virtually all cetaceans reported were harbour porpoises. Annual estimates of incidental catch of small cetaceans varied greatly between fisheries and areas. Confidence intervals were large due to variation in reported incidental catch rates among individual fishers and geographic areas. Most small cetaceans were reported in the nearshore cod fishery, although there were also numerous reports of catches in nearshore fisheries for lumpfish, herring and Greenland halibut. Incidental catch of small cetaceans was also identified in offshore fisheries for monkfish, white hake and Greenland halibut. Most incidental catch events occurred during the third quarter of the year (July-September) along the south coast, although catches of harbour porpoises were also reported during the second and fourth quarters.

Several strategies could be implemented to better monitor small cetacean incidental catch in Newfoundland and Labrador waters. However, harbour porpoise population estimates are required before it can be determined if this fisheries-related mortality occurring in Newfoundland is sustainable.

KEYWORDS: HARBOUR PORPOISE; INCIDENTAL CATCHES; GILLNETS; NORTH ATLANTIC; FISHERIES; NORTHERN HEMISPHERE

INTRODUCTION

Despite reduced fishing effort in many North Atlantic fisheries following the collapse of groundfish stocks in the early 1990s, concerns remain about the sustainability of a number of harbour porpoise (*Phocoena phocoena*) populations (e.g. Stenson, 2003). Although potential limiting factors for these populations include habitat change, changes in prey abundance or distribution, marine pollutants and global warming (Aguilar and Borrell, 1995; Anon., 1999; Brodie, 1995; Donovan and Bjørge, 1995; Hutchinson, 1996; Koschinski, 2002; Teilmann and Lowry, 1996); direct mortality, primarily through incidental catches in fishing gear, remains the primary concern. The harbour porpoise is known to be particularly vulnerable to incidental catches in fishing gear; they are most often caught in bottom-set gillnets and to a lesser extent fish weirs and traps (Berggren *et al*., 2002; Gaskin, 1984; IWC, 1994; Larrivée, 1996; Lesage *et al*., 2006; Read and Gaskin, 1988; Smith *et al*., 1993; Stenson, 2003; Trippel *et al*., 1996).

A number of reviews (Anon., 1998; CEC, 2002; Donovan and Bjørge, 1995; Jefferson and Curry, 1994; Read, 1994; Stenson, 2003) have concluded that large numbers of porpoises are caught in commercial fishing gear throughout their range. Based upon declining sightings and/or the perceived impacts of incidental catches, many porpoise populations have been classified as being at risk by either national or international groups responsible for assessing the status of such populations. In Atlantic Canada, harbour porpoises are currently listed as of 'special concern' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2003a; 2003b).

Although incidental catches of harbour porpoises are known to occur in a number of fisheries in Newfoundland and Labrador, Canada, there are few reliable estimates of such catches (DFO, 2001; Lien, 2001; Lien *et al*., 1988). Substantial harbour porpoise catches are thought to have occurred in the past, since this region has traditionally supported large gillnet fisheries (mainly for Atlantic cod, *Gadus morhua*). Previous information on cetacean incidental catch in Newfoundland fisheries was summarised by Lien *et al*. (1988) and subsequently by the Canadian Department of Fisheries and Oceans (DFO) (DFO, 2001; Stenson, 2003). 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; Lien, 2001; Lien *et al*., 1994). Unfortunately, given the limitations of the available data these estimates were extrapolated from reported catches by a limited number of fishermen, often in restricted areas of the province. In addition, none of the estimates had detailed fishing effort data associated with them, mainly because the scale of the fishery (large numbers of small vessels fishing in often-remote locations) has historically made total fishing effort in Newfoundland and Labrador difficult to determine. Therefore, these previous estimates of incidental catch in Newfoundland are biased to an unknown extent, and should only serve as a first indication of the magnitude of incidental catch (DFO, 2001).

As in most areas of the Northwest Atlantic, total landings in the Newfoundland and Labrador cod fishery have been reduced significantly since the 1980s (DFO, 2006b; 2006c; Hutchings and Myers, 1995; Shelton *et al*., 2006). As an example, catches of northern cod in Northwest Atlantic

* *Memorial University of Newfoundland, Whale Research Group, Biology Annex, 297 Mt. Scio Road, St. John's, NL, Canada A1C 5S7.*
+ *Marine Mammal Section, Department of Fisheries and Oceans, P.O. Box 5667, NAFC, 80 East White Hills Road, St. John's, NL, Canada A1C 5X1.*

Fisheries Organization (NAFO) Divisions 2J+3KL dropped from approximately 240,000mt in 1988 to 2,300mt in 2006 (DFO, 2006a; 2006b); catches in other areas suffered similar declines. Because of this, the fishery, which accounted for the majority of harbour porpoises caught in this region (DFO, 2001; Lien *et al*., 1994; Read, 1994), was closed off the northeast coast of Newfoundland in 1992 and off the south and west coasts in 1993. Cod gillnet fisheries have reopened since 1997, but at much reduced levels. The fishery off the northeast and western coasts of Newfoundland was closed again in 2003, but a limited fishery reopened in 2006. Incidental catches of harbour porpoises were probably significantly reduced during these moratoria and may continue to be less than prior to 1992 (DFO, 2001). Evidence of such 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; Trippel and Shepherd, 2004; Waring *et al*., 2001). However, recent reports from both the industry and Fishery Observers indicate that porpoises continue to be caught regularly despite reduced fishing effort since the early 1990s.

Historically, there has been relatively little effort to monitor marine mammal incidental catch in fisheries in Newfoundland and Labrador. Data are available through a fishery logbook programme, combined with directed phone surveys and interviews (DFO, 2001; Lien, 2001; Lien *et al*., 1994; 1988) but they are limited in time or geographic coverage. Independent incidental catch observers have been recommended as the best means to monitor incidental catches (IWC, 1994), but these proposals have not been widely implemented in Newfoundland and Labrador because much of the local fishery is conducted using small vessels (<10m). Fishery Observers are present aboard some larger fishing vessels, but they provide limited coverage of most fleets, and their primary duty is to document catch levels of directed fish species rather than identifying marine mammal incidental catch. Since 1989, DFO has maintained a network of commercial fishermen throughout the province (hereafter referred to as Bycatch Collectors), who collect and report marine mammal incidental catch as well as detailed fishing effort data. In addition, fishermen involved with the scientifically-managed Sentinel fishery for Atlantic cod were asked to retain and report small cetacean catches.

All available data on fishing effort and catches were reviewed in order to gain a better understanding of recent levels of small cetacean incidental catch in Newfoundland and Labrador, Canada. This paper presents the results of incidental catch analyses of the nearshore gillnet fisheries for Atlantic cod, lumpfish (*Cyclopterus lumpus*), Atlantic herring (*Clupea harengus*) and Greenland halibut (*Reinhardtius hippoglossoides*), as well as the offshore gillnet fisheries for monkfish (*Lophius americanus*), skates (*Rajidae*), white hake (*Urophycis tenuis*) and Greenland halibut, for the years 2001-2003. These fisheries were considered to be the most likely to take harbour porpoises in Newfoundland and Labrador waters based on previous reports of incidental catch.

METHODS

Estimates of harbour porpoise incidental catch were obtained using combinations of fishing effort and incidental catch rate multipliers derived from bycaught porpoises reported by Bycatch Collectors, the Sentinel fishery and/or 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. All data were grouped geographically according to NAFO divisions of Newfoundland and Labrador waters (Fig. 1).

Databases used to estimate incidental catch in this study included a catch-effort database for vessels ≥35ft long (10.7m, hereafter quoted in feet), a fish landings database for vessels <35ft, a Fishery Observer database, a Sentinel Fishery database and a Marine Mammal Bycatch Collector database (see descriptions below). These databases contained records from all types of gillnet fisheries, with the greatest geographical and temporal effort being in the Atlantic cod fisheries. This fishery is of great importance because of the large number of fishers that participate in it, as well as the relatively large amount of data available for this fishery.

Fishing effort data

Catch-effort database for vessels greater than or equal to 35 feet long

The Policy and Economics Branch at DFO in St. John's maintains a catch-effort database for vessels ⩾35ft. This database contains detailed information on total fish landings, general species composition and landed catch by individual species (both gutted and round weight). However, its usefulness in estimating fishing effort was reduced because total soak time and amount of gear deployed were not always reliably recorded by all fishers. When possible, data from the Fishery Observer database (see below) were used in combination with the landed catch data to better calculate total fishing duration, or total amount of gear deployed.

Fish landings database for vessels less than 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 for small vessels (<35ft). These were often the only data available for these vessels and contained the total landed catch for all trips for every vessel, both in gutted and round weight, for individual species. However, this database suffers from both a lack of effort information (no data on either the duration of the trip, or the number of nets deployed by a vessel) and the lack of any detailed geographical information as to where the fish were caught. Given the small vessel size and likelihood that fishing occurred near to their point of departure, catches are assumed to have been taken in the NAFO unit of the home port.

An additional, separate logbook database for the nearshore fishery for Atlantic cod and associated groundfish was set up by researchers in the Groundfish Section at DFO in St. John's in 1997, to address perceived deficiencies in the existing catch/effort and landings databases. This database contained detailed fishing effort data on a per-day basis, and was only used to derive a corroborative measure of net-days for all vessels. Unfortunately, this database did not contain all fishing effort as not all vessels submitted their logbooks.

Incidental catch data

Marine Mammal Bycatch Collector database

The Marine Mammal Bycatch Collector Programme database consisted of extremely detailed reports on a variety of fisheries since its inception in 1989. Fishermen recorded, for all their commercial gillnet fishing effort, location of sets, water depth, net characteristics, the number of nets hauled daily, soak time, catch (fish, seabirds and marine

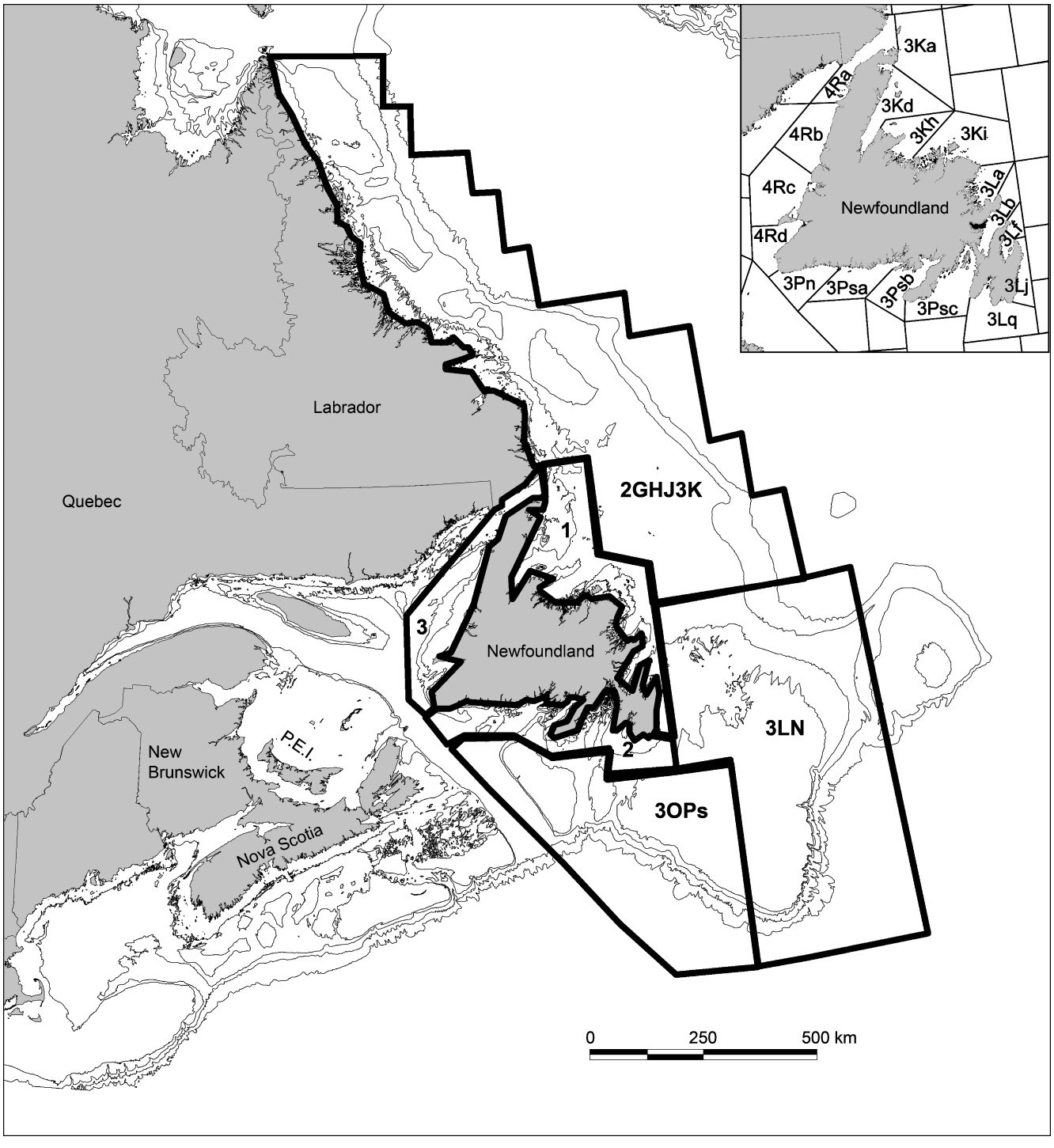

Fig. 1. An overview of Newfoundland and Labrador waters, showing geographical units used to aggregate fishing effort and incidental catch data. 1=Northeast coast; 2=South coast; 3=West coast. Individual nearshore NAFO units, as referred to in the text, are described in the inset. 100m, 200m, 1,000m and 2,000m depth increments are indicated.

mammals) and discards. In many cases, information on location of catches was limited (usually identified by a local landmark) but the boats employed were small (<35ft), so it is assumed that the majority of catches were made close to the home port. Vessels in this programme were most active in the gillnet fisheries for Atlantic cod, lumpfish and other species such as winter flounder (*Pseudopleuronectes americanus*), but other fisheries were less well covered by the present Collector Programme.

DFO selected these vessels because they participated in fisheries that were known to have high incidental catches of seals (e.g. the lumpfish fishery). However, small cetaceans, especially harbour porpoises, were also reported regularly. In 2001, efforts to collect data on small cetacean incidental catches were increased by specifically asking participating vessels to record the capture of each individual. The number of participating vessels that sent in forms varied from year to year (n=47 in 2001, n=45 in 2002, and n=29 in 2003), depending on individual decisions on what fishery to prosecute. Over 80% of vessels who initially agreed to collect the requested information sent in their forms the same year, although this rate declined slightly in following years. Most fishermen who participated in the programme had been doing so for many years, and were familiar with

the data requirements; those who did not return the proper information were subsequently excluded from the programme.

Sentinel Fishery database

The Sentinel Fishery database consisted of detailed fisheries data collected from the scientifically-managed Sentinel Fishery for Atlantic cod (n=81 nearshore vessels in 2001 and 2002, n=58 in 2003). This fishery was established in 1995 after the introduction of the groundfish moratorium to enable a continued monitoring of the cod stocks in nearshore waters in the absence of data from the commercial fleet by fishing under scientifically designed protocols. Vessels involved are almost all <35ft, and their effort is limited (normally up to six nets, set for short periods), but the fishery is considered to be generally comparable in geographic range to the commercial nearshore cod fishery, which uses the same range of vessel sizes. As such the Sentinel Fishery data offers an opportunity to obtain measures of catch per unit effort for small-boat, nearshore fisheries. However, there may be differences in terms of the location and soak times of the nets, which may not correspond exactly to the commercial fishery and lead to divergent catch rates per unit effort.

Fishers participating in the Sentinel Fishery reported incidental catches of marine mammals to DFO's Marine Mammal Section in St. John's. They were asked to report incidental captures in their cod fishery only, unless they were recruited to the Bycatch Collector programme separately. 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 (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. In cases where Sentinel cod catch rates differed significantly from Bycatch Collector rates, Sentinel data were not used.

Fishery Observer database

The database associated with the DFO-managed Fishery Observer Programme provided an independent estimate of fishing effort and records of small cetacean incidental catch events, primarily in large (≥35ft) vessels. Observers recorded, among other things, the exact amounts of catch and discards, exact geographical fishing 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 gillnet fisheries currently takes place on vessels targeting deepwater species such as Greenland halibut and monkfish. In practical terms, there is only limited opportunity for Fishery Observers to board small vessels (<35ft long), and there is no protocol in place to ensure randomised deployment of observers on these vessels (J. Firth, DFO-NL, pers. comm.; NMFS, 2003). Therefore, observer coverage was not directly related to fishing effort (D. Kulka, DFO-NL, pers. comm.). In addition, documenting marine mammal bycatch is not the primary focus of most observers, so events may go unreported. For this reason, it was decided to use the Fishery Observer database only to study incidental catch in offshore fisheries, particularly the gillnet fisheries for monkfish, skates, white hake and Greenland halibut, where Bycatch Collector data were limited or absent. In cases where records of the same trip were available from two or more sources, data from trips monitored by a Fishery Observer were used to correct for reporting errors.

Unfortunately, it is uncertain as to how many animals were involved in a given incidental capture event recorded in this database. Fishery Observers reported the total discarded weight of the small cetaceans of each individual capture event without recording the number of animals, and this, combined with occasional uncertainty in species identification, made it difficult to estimate total numbers of cetaceans caught incidentally in these fisheries. Minimum numbers caught were estimated based on average weights reported in the literature.

Deriving estimates of small cetacean incidental catch

Small cetacean incidental catch events were recorded through the data collection programmes described above. Rates of bycaught 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. The unit of effort used in these calculations was the number of net-days (number of nets set, multiplied by the total number of days fished).

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 and 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; Fig. 1) and analysed for all three coasts separately. Incidental catch estimation analyses were performed at the geographic scale of coastlines, because it appeared unlikely that porpoises either restricted themselves to a single NAFO unit or were distributed uniformly around the island of Newfoundland (Johnston *et al*., 2005). 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. However, fishing effort has been limited in this area, and it is unlikely that large numbers of small cetaceans would have been captured here. Offshore fisheries were analysed at larger geographic scales, based on a combination of oceanographic and jurisdictional boundaries (NAFO Divisions 2GHJ3K, 3LN and 3OPs; Fig. 1).

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 for these fishers. These estimates were based on the relationships 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.

Small cetacean incidental catch rates were calculated using fishing trips of individual fishers as 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.

Sample sizes were frequently small and difficult to analyse with conventional statistics (Efron and Tibshirani, 1993; Simon, 1997). Therefore, the uncertainty associated with estimates of incidental capture was assessed using a resampling procedure (Blank *et al*., 2001). Unlike conventional statistics, resampling methodology does not require assumptions about the distribution of the dataset, and can be used with comparatively small samples.

These incidental catch rate values were resampled 10,000 times, with replacement. This generated a population of 10,000 averages based on individually-resampled incidental catch estimates from all individual fishers, for the relevant geographical scale. The overall mean incidental catch rate per unit effort, and the 2.5th and 97.5th percentile rates from this population, were then used to estimate mean catches as well as upper and lower limits of a 95% confidence interval around the mean. These estimated incidental catch rates were multiplied by fishing effort data for the entire fishery for that area and time of year to estimate total incidental catches of small cetaceans.

RESULTS

Records of incidental capture of small cetaceans in 2001-03

Bycatch Collector reports and Sentinel programme data

Totals of 39, 64 and 35 reports of incidental catch of small cetaceans were received through the Bycatch Collector programme and the Sentinel programme in 2001, 2002 and 2003, respectively, totalling 138 records (Table 1). 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 species identification could not be independently verified. However, based on discussions with Bycatch Collectors, most unidentified small cetaceans were probably harbour porpoises, although some may have been Atlantic white-sided dolphins (*Lagenorhynchus acutus*), whitebeaked dolphins (*L. albirostris*) or common dolphins (*Delphinus delphis*).

Most of the reported bycatch events occurred in the nearshore cod gillnet fishery (28 reports out of a combined total of 2.17×10^4 net-days for Bycatch Collectors and 63 reports out of 2.95×10^4 net-days for Sentinel fishery, for all years combined). The remainder of catches were reported in the nearshore fisheries for lumpfish roe (25 reports out of 5.09×10^4 net-days), herring (six reports out of 2.38×10^3 net-days) and Greenland halibut (three reports out of 1.04×10^4 net-days), as well as the offshore fishery for monkfish and skate (three reports out of 5.18×10^3 net-days). Most of the recorded catches (101 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 four animals (including cow-calf pairs) were occasionally reported (nine times over three years).

There was considerable intra-annual variation in bycatch rates (number of small cetaceans/net-day) among fishers within the same area, as well as variation in bycatch rates from the same fishers in consecutive years. In any given year, most fishers did not capture any small cetaceans, but some captured up to eight animals. During 2001-2003, high porpoise catches were reported from several areas, including waters around 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; Fig. 1).

Fishery Observer Programme data

A total of 10, 24 and 3 records of cetacean incidental catch events were recorded by the Fishery Observer Programme in 2001, 2002 and 2003, respectively (Table 1). Bycatches

Table 1

An overview of the incidental catch events of small cetaceans recorded by the Bycatch Observer and Sentinel programme, and the Bycatch Observer programme, during 2001-03.

	Number of bycaught small cetaceans per year, reported by Bycatch Collectors (and Sentinel fishers for cod fishery)			Number of small cetacean catch events per year, reported by Fishery Observers[2]		
Fishery	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	0
Monkfish/skate (offshore)	0	3	0	1	21	3
White hake (offshore)	0	0	0	0	1	0
Greenland halibut (nearshore)	0	3	0	0	0	0
Greenland halibut (offshore)	0	0	0	1[3]	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 had become aware of DFO's collection efforts through word of mouth. Ten of these porpoises had been caught in the nearshore cod fishery, while a single porpoise was caught in a lumpfish gillnet. Since these porpoises did not have any netday-effort associated with them, they were not used in further analyses. This problem did not occur in other years.

[2] Fishery Observers did not specifically record the numbers of individuals involved in an incidental catch event, only total weight. Minimum numbers of animals were estimated based on average weights reported in the literature.

[3] This incidental catch event involved at least one long-finned pilot whale, as mentioned in the text.

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; most of these catches were recorded on board small vessels (<35ft). There was a single report of small cetacean bycatch in the offshore gillnet fishery for white hake, in 2002 and another one in the offshore fishery for Greenland halibut in 2001. All these reports referred to various species of dolphins as well as harbour porpoises. Since Observer coverage levels in the nearshore cod fishery were low compared to Bycatch Collector and Sentinel datasets, it was decided to not use these data to estimate incidental catches of small cetaceans in this fishery.

Fishing effort and associated bycatches in Newfoundland and Labrador

Atlantic cod

The number of vessels participating in the Atlantic cod fishery varied from 3,126 in 2001, to 2,708 in 2002, to 962 in 2003 (Table 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 14cm mesh size. In 2001 and 2002, most cod fishing effort occurred in nearshore waters along the south and west coasts of Newfoundland; there was relatively little effort offshore off the south coast. In 2003, the cod fishery along the east/northeast and west coasts of Newfoundland was closed for conservation purposes, limiting the directed cod fishery to the Sentinel fishery in those areas and reducing the total number of vessels to 962, fishing mainly off the south coast where a commercial fishery for cod continued on a limited basis (DFO, 2006b; 2006c; Table 2). Landings were highest in July-September (third quarter) of each year, but considerable amounts were also landed in the fourth quarter (Fig. 2). Observer coverage for this fishery was relatively low – an observer was present on less than 10% of trips.

There were no reports of any incidental catches in the only currently operating offshore fishery for cod, off the south coast of Newfoundland. Therefore, incidental catch estimates were only calculated for the nearshore fishery in waters around the island and are presented for each quarter

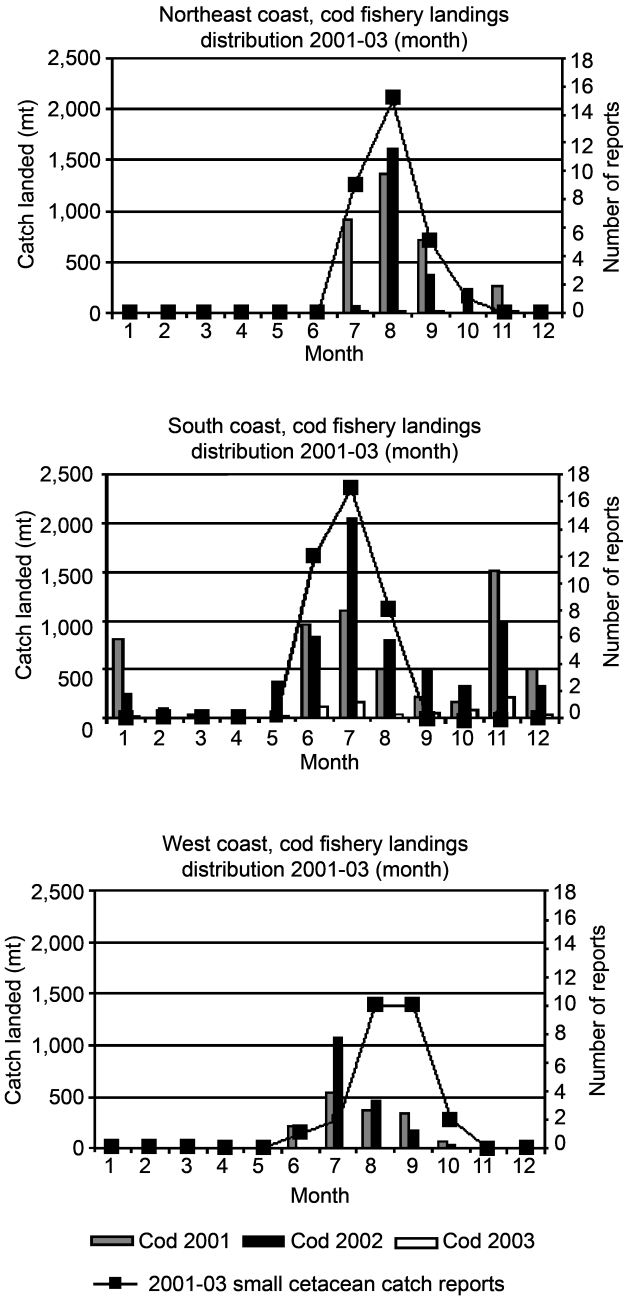

Fig. 2. Distribution of fishing effort and number of recorded small cetacean bycatch reports in the nearshore cod gillnet fishery, for Northeast, South and West coast, for 2001, 2002 and 2003. Small cetacean catch reports are combined for the three years.

Table 2

An overview of landings and effort data for the gillnet fisheries during 2001-03 that were used in this study.

	Number of vessels active in the fishery, per year			Total Catch (mt) per year			Fishing effort (net-days, estimated) per year		
Fishery	2001	2002	2003	2001	2002	2003	2001	2002	2003
Cod (nearshore)	3,126	2,708	962	10,264	10,233	6,284	907,309	1,073,606	793,147
Cod (offshore)	119	147	136	1,394	1,913	1,780	14,299	22,256	17,546
Lumpfish (nearshore)	1,528	811	1,009	872	171	554	218,263	123,315	126,353
Herring (nearshore)	207	196	97	1,430	1,660	1,025	32,073	23,052	14,140
Monkfish/skate (offshore)	36	58	90	942	3,027	2,659	154,467	251,575	211,549
White hake (offshore)	38	24	22	305	345	278	5,907	12,371	9,989
Greenland halibut (nearshore)	273	104	115	1,687	868	1,321	416,933	315,928	1,695,817
Greenland halibut (offshore)	112	96	49	7,237	5,277	3,517	2,563,700	2,135,685	6,674,892

of the year (Table 3). Based on recovered carcasses, all of these animals were probably harbour porpoises. The average annual incidental catch estimates were 688 animals (95% CI: 102-1,715) in 2001, 1,296 animals (95% CI: 365-2,632) in 2002 and 2,001 animals (95% CI: 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). There were very few reports of incidental catches during October-December and none during January-March (Table 4; Fig. 2). The seasonal presence of harbour porpoises in waters around Newfoundland is apparent from the distribution of incidental catch reports, relative to the monthly amount of fish landed (Fig. 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 and 1,009 in 2003. Nets used in this fishery typically have a 25cm mesh size. There have been substantial fluctuations in landings in recent years (Table 2). 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 (an observer was present on less than 1% of trips).

Based on collected specimens, all of which were harbour porpoises, 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% CI: 2-240; Table 3). Bycatch Collectors did not report any incidental catch of small cetaceans in 2002, when poor catches were reported in the lumpfish fishery (Table 2). A 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% CI: 20-499).

Table 4

Monthly distribution of incidental catch reports of small cetaceans in the nearshore cod fishery during 2001-03 around the island of Newfoundland, separated by coastline. Reports originated from Bycatch Collectors and Sentinel fishers, and include records of animals that were not collected for independent identification.

	2001			2002			2003		
Month	East coast	South coast	West coast	East coast	South coast	West coast	East coast	South coast	West coast
Jan.	-	-	-	-	-	-	-	-	-
Feb.	-	-	-	-	-	-	-	-	-
Mar.	-	-	-	-	-	-	-	-	-
Apr.	-	-	-	-	-	-	-	-	-
May	-	-	-	-	-	-	-	-	-
Jun.	-	3	-	-	3	1	-	6	-
Jul.	3	1	1	3	9	1	3	7	-
Aug.	7	-	3	6	8	7	2	-	-
Sep.	1	-	2	3	-	4	1	-	4
Oct.	-	-	1	1	-	1	-	-	-
Nov.	-	-	-	-	-	-	-	-	-
Dec.	-	-	-	-	-	-	-	-	-

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 occurs along the west coast of the island, particularly in NAFO unit 4Ra (the Strait of Belle Isle). Nets used in this fishery typically have a 6cm mesh size. Numbers of participating vessels declined from 207 in 2001 and 196 in 2002, to 97 in 2003. Total landed catches were variable during this time (Table 2). 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 (Table 3). There was virtually no Fishery Observer coverage of this fishery.

All incidental catches in this fishery occurred during July-September. Based on collected specimens, all of which were harbour porpoises, it is assumed that the small cetaceans caught in the nearshore herring fishery were porpoises. In 2001, the average incidental catch estimate for the nearshore herring fishery was 89 harbour porpoises (95% CI: 26-176; Table 3). Bycatch Collectors did not report any incidental

Table 3

Estimated catches of small cetaceans (the vast majority are likely to be harbour porpoise) in nearshore and offshore gillnet fisheries in all areas of the island of Newfoundland, based on net-days, for 2001-03. 'N/A' indicates that no 95% confidence interval could be calculated due to small sample size.

			2001		2002		2003	
Fishery	Scale	Quarter	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
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	102-1,442	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	130-2,135	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, and identified as a harbour porpoise.

catch of small cetaceans in 2002. In 2003, the total average incidental catch estimate for the nearshore herring fishery was 10 small cetaceans (95% CI: 0-29).

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 1,000m (DFO, 2000); (Fig. 1). Only large vessels (⩾35ft) participated in this fishery. Nets used in this fishery have a 30cm mesh size. The number of participating vessels has increased over time, with 36 vessels in 2001, 58 in 2002 and 90 vessels in 2003. Total landed catches of monkfish and skate also increased significantly in recent years although fishing effort peaked in 2002 (Table 2). 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 being present on approx 30% of trips.

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% CI: 0-4), based on net-days (Table 3). By 2002, these estimates had increased to an annual average of 60 small cetaceans (95% CI: 33-92), of which approximately six 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 six animals. In 2003, annual rates of incidental catch had again declined to approximately five small cetaceans (95% CI: 0-12).

White hake

The majority of the gillnet fishery for white hake takes place in offshore waters along the southern edge of the Grand Banks (NAFO Divisions 3O and 3Ps), where the species reaches its northernmost distribution (Fig. 1). Only large vessels (⩾35ft) participated in this offshore fishery, although small catches were also made in nearshore waters along the south coast by some small-boat fishers. Nets used in this fishery typically have a 14cm mesh size. The number of participating vessels decreased from 38 vessels in 2001, to 24 in 2002 and 22 in 2003. Total landed catches and fishing effort varied considerably among years (Table 2). 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. There was no Fishery Observer coverage of the nearshore component of this fishery. Fishery Observer coverage in the offshore fishery ranged between 4 and 14% of trips.

For 2001 and 2003, no incidental catch events were reported. In 2002, the total average incidental catch estimate was 29 porpoises (not resampled; Table 3). This was based on one bycatch event of a harbour porpoise (Table 1).

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 1,400m, with concentrations in NAFO Divisions 0B, 2J3KL and 3O (Fig. 1). 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). Vessels fishing offshore were all large (⩾35ft), but in the nearshore areas, smaller vessels also participated. Greenland halibut nets normally have a 19cm mesh size. The number of vessels involved 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 while fishing effort increased significantly in 2003 (Table 2). Incidental catch estimates for the nearshore fishery were calculated for each quarter of the year. The majority of fishing effort was concentrated in the summer months, during the second and third quarters of the year. Fishery Observers were present on approximately 5 to 10% of offshore trips and approximately 1% of nearshore trips.

All incidental catches occurred in the second and third quarter of the year, and all reported small cetaceans were harbour porpoises. It is therefore assumed that the small cetaceans caught incidentally in this fishery were probably harbour porpoises. For 2001 and 2003, no incidental catches were reported in the nearshore fishery. In 2002, the total average incidental catch estimate was 29 small cetaceans (95% CI: 0-78; Table 3). 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.

Total incidental catch

Average incidental catch estimates for small cetaceans (most of which were probably harbour porpoises) ranged from 862 in 2001, to 1,428 in 2002 and 2,228 in 2003. The nearshore cod gillnet fishery accounted for 3,985 incidental catches for the three-year period of 2001-03, or an average of 1,328 catches per year. If this estimate is combined with the annual mean incidental catch estimates for small cetaceans in the nearshore lumpfish fishery (98), the nearshore herring fishery (33) and the nearshore Greenland halibut fishery (9), approximately 1,469 small cetaceans have been incidentally caught annually in these nearshore gillnet fisheries in Newfoundland in 2001-2003 (Table 3). Annual mean incidental capture estimates of small cetaceans in the offshore fishery for monkfish are probably in the low tens to low hundreds, and probably involve common and Atlantic white-sided dolphins, although small numbers of harbour porpoises are thought to have been captured as well. In the offshore white hake fishery, harbour porpoises has been reported bycaught, although it would seem that other small cetaceans are also at risk. The annual mean incidental capture estimate of small cetaceans in the offshore fishery for white hake is approximately 10 animals. The single long-finned pilot whale capture event in the offshore Greenland halibut fishery was not used to estimate catch for the entire fishery, since it is widely distributed along the continental shelf break and the areas where it overlaps with pilot whales are unknown.

DISCUSSION

Estimated small cetacean incidental catch in 2001-03

Based on data presented here, annual mean incidental catch estimates of small cetaceans, the majority of which are

probably harbour porpoises, in Newfoundland fisheries were approximately 1,469 animals per year, with the vast majority of these occurring in nearshore fisheries around the island of Newfoundland.

In the late 1980s, a total of 2,242 harbour porpoises were estimated to have been caught in Newfoundland, based on a telephone survey of fishermen (DFO, 2001; Lien, 2001). At the very least, this estimate provides an indication of the level of incidental catches that may have been taking place at the time. Although the current estimate is lower, the confidence limits derived in the present study are large, and thus it is difficult to determine if the new estimates represent a change in incidental catches since the onset of the 1992 moratoria. However, the reduction in fishing effort has probably led to a decrease in catches of harbour porpoises. In the Gulf of Maine, fish stock conservation measures to reduce fishing effort from 1999 onward were partially responsible for a subsequent decrease in incidental catches of harbour porpoises in US waters (DFO, 2001; Rossman and Merrick, 1999; Trippel and Shepherd, 2004; Waring *et al*., 2001).

The overall increase in estimated catches from 2001-03 is principally driven by an increase in catch rates in the nearshore cod fishery, particularly in 2003. The cause for these fluctuations in harbour porpoise catch rates is presently unknown; however, in 2003, one participating Sentinel fishermen reported especially high porpoise catches per net-day during most of his fishing season, which has likely led to a positive bias in the overall estimate. However, this apparent increase may also have been driven by underlying variability in harbour porpoise abundance in nearshore Newfoundland waters.

The wide confidence intervals associated with these estimates are indicative of the variability associated with incidental catches of small cetaceans. Catches occur only during a low number of fishing trips, but when they happen, a large number of animals may be caught. As a result, individual catch rates include a large number of zeroes with only a few catch rates greater than zero, and sometimes quite large. 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 results in highly variable estimates of incidental catch.

The fisheries discussed here represent the vast majority of current gillnet fishing effort in Newfoundland and Labrador. Several other fisheries targeting species such as haddock (*Melanogrammus aeglefinus*), are currently active at very low levels, particularly off the south coast. No reports of incidental catch in these fisheries have been received, but it is likely that they experience catch rates similar to the cod fishery since these species occur in the same areas and seasons, and are fished with nets of comparable mesh sizes. However, the current low level of fishing effort (due to low fish stock sizes) would suggest that levels of incidental catch in these fisheries are not large.

There may be several reasons why there is such variation in reported incidental catch, with some vessels having larger harbour porpoise catches than others. Perhaps some are operating in harbour porpoise 'hotspots' where there is an overlap of harbour porpoises and their prey, or simply areas of higher harbour porpoise density. There were not enough data in this study to provide strong evidence of such '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; Fig. 1), based on the repeated occurrence of captured porpoises in these areas. Unfortunately, our understanding of the relationship between harbour porpoise abundance and incidental catches, as well as the influence of other factors such as prey abundance and distribution, is limited. Harbour porpoises are known to use oceanographic features such as fronts and island wakes while foraging, and it is possible that 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 confirms that harbour porpoises are only present during the summer and fall months in waters around the island of Newfoundland (Richardson, 1992; Fig. 2). Generally speaking, porpoises are captured from May-October, initially in the lumpfish fishery, and subsequently 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, while 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 those along the other coasts, and leave for presumed wintering grounds off the eastern coast of the United States at an earlier date (Rosel *et al*., 1999). Alternatively, they 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 utilise the nearshore environment around Newfoundland through the entire year.

It is presently unknown exactly how the fisheries for monkfish, skates and white hake capture pelagic dolphins such as common and Atlantic white-sided 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 (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 from year to year, as there is no evidence for a geographical redistribution of fishing effort over this period. Possible reasons might include an increased focus among some Fishery Observers on documenting small cetacean incidental catch, or an influx of pelagic dolphins in response to temporarily favourable conditions in 2002. 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 (NMFS, 2005a;2005b; Reeves *et al*., 2002). Stochastic fluctuations in prey availability may have led to a periodically higher abundance of these species in areas targeted by the monkfish and skate fishery in 2002.

Caveats for incidental catch estimation and means to improve incidental catch monitoring in Newfoundland and Labrador

In recent years, there have been many changes to the gillnet fisheries in Newfoundland and Labrador which may have reduced the effectiveness of existing incidental catch monitoring programmes. Most contributors to the Bycatch

Collector programme target nearshore groundfish species (particularly cod and lumpfish), but coverage is limited in small pelagic species such as herring, or offshore fisheries (particularly for monkfish and skates). The subsample of vessels used to derive incidental catch multipliers could also be unrepresentative of the entire fleet e.g. the Sentinel fishery may cover other areas than the commercial fishery where the density of harbour porpoises might be different; or fishermen change their fishing behaviour when a Fishery Observer is present (Lesage *et al*., 2006). The Sentinel fishery reported more incidental catches of harbour porpoises per net-day than Bycatch Collectors; however the extent of spatial overlap between Sentinel and commercial fisheries could not be investigated due to widespread lack of information on the geographical location of Bycatch Collectors' fishing gear. A more detailed comparison between adjacent Sentinel and commercial gillnets might uncover subtle differences in fishing methodology that influence catch rates of harbour porpoises, as described by Lesage *et al*. (2006).

Inaccurate reporting may occur due to difficulties in correct cetacean species identification by some participants or under-reporting. In this study, it is unlikely that Bycatch Collectors would underreport their incidental catches given their skill and motivation (most have a long working relationship with DFO's Marine Mammals Section). Additional training in cetacean identification, as well as reporting actual numbers of animals involved, might reduce the uncertainty in incidental catch reports by Bycatch Collectors and Fishery Observers, in cases where animals could not be collected. Further improvements in fishing effort data collection could be achieved through stricter adherence to the requirement that fishers complete their logbooks accurately and submit them following each season.

Deploying dedicated observers on every boat has been suggested as the ideal way to improve incidental catch reporting (IWC, 1994). However, this is impractical for many nearshore Newfoundland fisheries as most vessels are small and the cost of such a programme would be prohibitive. The Fishery Observer programme could be expanded to include more trips in nearshore fisheries, such as those for cod, lumpfish and herring, to provide an independent indication of incidental catch. However, concerns remain about placing observers on small boats with regards to observer safety and the potential impact of their presence on fishing operations (Lesage *et al*., 2006; NMFS, 2003).

CONCLUSIONS

As of yet, population sizes for most cetacean species in this part of the Northwestern Atlantic remain unknown, so the potential threat to the existence of these populations arising from this incidental catch is also unknown. Harbour porpoises in eastern Canadian waters are currently managed as three subpopulations, in the Gulf of Maine/Bay of Fundy area, the Gulf of St. Lawrence (including the west coast of Newfoundland) and around the south and east coasts of Newfoundland and northwards along the coast of Labrador (Gaskin, 1984;1992; IWC, 1996). It is unclear to what extent the various fisheries discussed here affect the different subpopulations around Newfoundland and Labrador, since porpoises are thought to seasonally migrate in and out of these waters, bringing them into contact with a variety of fisheries (COSEWIC, 2003a). In addition, there is evidence for long-range movements between porpoise subpopulations, indicating that fisheries may affect more than one local subpopulation (Read and Westgate, 1997; Rosel *et al*., 1999; Westgate and Tolley, 1999).

Means to improve the quality of data collected by deploying dedicated observers on every boat are unfeasible here, although a greater focus of the existing Fishery Observer programme on larger vessels active in these fisheries is possible. At the moment, fostering a long-term, trusting relationship with a number of representative fishers appears to be the best strategy to limit under-reporting of incidental catch.

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