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Harbour Porpoise Bycatch Estimates For Newfoundland's 2002 Nearshore Cod Fishery

Estimation des captures accidentelles de marsouins communs par les pêcheurs de morues du littoral de Terre-Neuve en 2002

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Abstract

Despite reduced fishing effort in a number of north Atlantic fisheries following commercial collapse, concerns remain about levels of direct mortality, primarily through incidental catches in fishing gear, of harbour porpoise (*Phocoena phocoena*). Although harbour porpoise bycatch is known to occur in a number of nearshore fisheries along the coast of Newfoundland, there are few defendable, quantified estimates. This report briefly describes the level and distribution of the Atlantic cod gillnet fishery in the nearshore of Newfoundland in 2002, a period when the fishery was severely reduced. Based on several sources of data (bycatch rates derived using different methods of reporting; groundfish landings and net days as measures of effort, with either individual fishers or fishing trips as the sampling units) we estimate the potential number of incidental catches of harbour porpoises in this fishery in 2002. Confidence intervals were estimated using resampling techniques.

Estimates of bycatch of small cetaceans in 2002, virtually all of which are harbour porpoises, varied greatly (from 1,324 to 12,649 animals in the nearshore cod fishery, depending upon the calculation method used). Most of these were caught in the third quarter of the year (July – September) along the south coast, although porpoise bycatch was also reported in the second and fourth quarters. Confidence limits were large due to variation in the reported bycatch rates among individual fishers and geographic areas. Given its lower data variability and fewer assumptions required during analysis, we have greater confidence in the cetacean bycatch estimates based on net days as a measure of effort, during fishing trips (rather than effort per fisher). Thus we conclude that it is most likely that approximately 1,500 to 3,000 harbour porpoises were incidentally caught for the nearshore cod gillnet fishery in Newfoundland in 2002. The 95 percentile range values around the derived estimates are wide (ranging from 126 to 5,605 for this type of approximation).

Several strategies could be implemented to better monitor small cetacean bycatch. Porpoise population estimates are required before we can determine if such mortality is sustainable.

Résumé

Malgré une diminution des efforts de pêche dans plusieurs pêches de l'Atlantique nord-ouest suivant un effondrement de la pêche commerciale, des craintes concernant les niveaux de mortalité directs de marsouins communs (*Phocoena phocoena*) demeurent, principalement en ce qui concerne les prises accidentelles dans les engins de pêche. Bien que les prises accidentelles de marsouins communs soient reconnues dans un bon nombre de pêches du littoral de Terre-Neuve, il existe peu d'estimations défendables et quantifiées. Ce rapport décrit brièvement le niveau et la distribution des activités de pêche de la morue de l'Atlantique, au filet maillant, au niveau du littoral de Terre-Neuve en 2002, une période durant laquelle la pêche fut sévèrement réduite. Selon plusieurs sources de données (les taux de prises accidentelles proviennent de diverses méthodes de collecte; débarquements de poissons de fond et jours nets en tant que mesures d'effort, avec soit le nombre de pêcheurs ou le nombre d'excursions de pêche comme unité d'échantillonnage), nous avons estimé le nombre potentiel de prises accidentelles de marsouins communs dans cette pêche en 2002. Les intervalles de confiance ont été estimés avec des techniques de ré-échantillonnage.

Les estimations de prises accidentelles de petits cétacés en 2002, pratiquement tous des marsouins communs, variaient grandement (de 1324 à 12649 animaux dans la pêche à la morue du littoral, dépendant de la méthode de calcul utilisée). La majorité de celles-ci ont été capturées dans le troisième quart de l'année (juillet – septembre) le long de la côte sud (particulièrement la baie de St. Mary's et la baie de Placentia), quoique des prises accidentelles de marsouins communs ont également été rapportées lors des deuxième et quatrième quarts. Les limites de confiance étaient larges en raison des variations du taux de prises accidentelles rapporté par chaque pêcheur et d'une zone géographique à l'autre. Nous avons une plus grande confiance envers les estimations de prises accidentelles de cétacés basées sur les jours nets, en tant que mesure d'effort, lors d'excursions de pêche (plutôt que l'effort pour chaque pêcheur) étant donné la moins grande variabilité de ces données et le peu de suppositions requises lors de l'analyse. Ainsi, nous concluons qu'il est plus probable qu'environ 1,500-3000 marsouins communs ont été pris accidentellement lors de la pêche aux filets maillants de la morue de l'Atlantique sur le littoral de Terre-Neuve en 2002. Les valeurs d'intervalles du 95e centile provenant des estimations sont larges, allant de 126 à 5605 pour ce genre d'approximation.

Plusieurs stratégies pourraient être mises en place pour mieux contrôler les prises accidentelles de petits cétacés. Les estimations de population de marsouins sont nécessaires avant que l'on puisse déterminer si de telles mortalités sont soutenables.

Introduction

Despite reduced fishing effort in a number of north Atlantic fisheries following collapse of the commercial groundfish fishery in the early 1990s, concerns remain about the sustainability 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, Anon. 1999, Koschinski 2002), the 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 (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).

A number of reviews (e.g., Jefferson and Curry 1994, Read 1994, Donovan and Bjørge 1995, Anon. 1998, CEC 2002, Stenson 2003) have shown 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 in danger by either national or international groups responsible for assessing the status of animals. In Atlantic Canada, the status of harbour porpoise is currently classified as "special concern" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2003), while the International Union for the Conservation of Nature (IUCN) considers harbour porpoise to be "vulnerable" throughout their range (Klinowska 1991).

Although harbour porpoise bycatch is known to occur in a number of nearshore fisheries along the coast of Newfoundland, there are few defendable quantified estimates. Substantial harbour porpoise catches are thought to have occurred since this area has traditionally supported large gillnet fisheries (mainly for Atlantic cod, *Gadus morhua*); recent reports indicate that porpoises continue to be caught despite reduced fishing effort since the cod moratoria ended in the late 1990's. Based on data for this study, in Newfoundland the Atlantic cod fishery appears to have a higher harbour porpoise bycatch rate relative to other net fisheries, such as bait nets and lumpfish (see also Lien et al. 1994, Read 1994, DFO 2001).

Available information on cetacean bycatch 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 bycatch of harbour porpoises was likely in the low thousands during the 1980s and early 1990s (Bjørge et al. 1994, DFO 2001). Unfortunately, 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 bycatch 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 western coasts of Newfoundland was closed again in 2003. Incidental catches of porpoise were probably significantly reduced during these moratoria (DFO 2001) and may continue to be less than prior to the moratoria. Evidence of such reductions in bycatch due to reductions in fishing effort is also available for the Bay of Fundy/Gulf of Maine population (Rossman and Merrick 1999, Waring et al. 2001). This reduction in bycatch may have had benefits for porpoise populations, although this has yet to be demonstrated.

In general, there has been relatively little effort to monitor marine mammal bycatch in most fisheries. Data in Newfoundland have been available through the fisher's logbook programme, combined with directed phone surveys and interviews. Independent bycatch observers have been recommended as the best means to monitor bycatch, but these proposals have not been implemented in Newfoundland. Fisheries observers are present aboard some fishing vessels (e.g., DFO's Observer Programme in Newfoundland, D. Kulka, DFO, St. John's, NL, pers. comm.), but they provide very limited coverage of the fleet, and the primary duty of these observers is to document catch level of directed species rather than identifying marine mammal bycatch. For the past four years, DFO has maintained a network of dedicated

fishermen spread throughout the province, who collect and report marine mammal bycatch, as well as detailed fishing effort data.

In order to gain a better understanding of the level of harbour porpoise bycatch in Newfoundland, we initiated a review of all available data on fishing effort and catches of harbour porpoise. This report describes the level and distribution of the Atlantic cod gillnet fishery in the nearshore of Newfoundland in 2002. Based on several sources of data (bycatch ratios derived using different methods of reporting; groundfish landings and net days per fisher or per trip as measures of effort) we estimated the potential number of incidental catches of harbour porpoises in this fishery in 2002.

Materials and Methods

Data were grouped by NAFO subunits for each of three coasts of Newfoundland: south coast (NAFO areas 3Pn, 3Psa, 3Psb, 3Psc and 3Lq combined), east/northeast coast (3Ka, 3Kd, 3Kh, 3Ki, 3La, 3Lb, 3Lf and 3Lj combined), and west coast (4Ra–d combined). Estimates of harbour porpoise bycatch were made using combinations of fishing effort and bycatch rate multipliers derived from bycaught porpoises reported by Sentinel fishers or fisheries observers (Figure 1).

Databases used to estimate bycatch 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 groundfish logbook database, a bycatch observer database, a Sentinel Fishery database, and Marine Mammal Bycatch Collector data (see descriptions below). These databases contained records from all types of fisheries, with the greatest geographical and temporal effort being the fisheries for Atlantic cod.

This fishery is of great importance because of the large number of fishermen that participate in it, as well as the significant amount of effort expended on monitoring the fishery. In addition, gillnets used in this fishery pose an entanglement risk for small marine mammals.

For these reasons, it was decided that the main focus of this study was to be on the nearshore gillnet cod fishery.

Nearshore gillnet fisheries catch/effort data on cod were organised based on the following parameters:

1. Vessel length (subdivided into <35 ft, 35-50 ft, 50-65 ft [15.2-19.8 m], and >65 ft [19.8 m]),
2. Time of year (divided into four quarters of the year, with January to March as the first), and
3. Area (divided by NAFO subunits), and analysed for each of three coasts, or overall.

This fishery is also conducted along the southeastern coast of Labrador (NAFO area 2Jm). For this fishery, no bycatch data were reported, and as such, this region has so far been excluded from further analysis.

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 larger vessels (≥35 ft). This database contained 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 gear deployment duration ("net days"), and amount of gear deployed was limited because these effort estimators were not reliably recorded by all fishers. When possible, data from the bycatch observer database (see below) have been 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 (<35 ft). This was often the only data available for these vessels and contained the total landed catch, 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 fisherman), and the lack of any detailed geographical information as to where the fish were caught.

Groundfish Logbook Database

A logbook database was set up by the Science Branch in 1997 as an alternative to the Statistics Branch's catch-effort database, which had been considered incomplete and inaccurate in certain areas. As a license condition, all fishers who fish for groundfish using vessels <35 ft long were required to keep and submit logbooks (E. Murphy, DFO, St. John's, NL, pers. comm.). The groundfish logbook database contained fishing effort data, primarily for the nearshore fishery for Atlantic cod and associated groundfish. The logbook database describes fisheries on a per-day basis, so that the entire catch for each day is recorded, with a description of the number of nets used, and the number of hours fished.

Bycatch Data

Bycatch Observer Database

The bycatch observer database contained records from the official, DFO-managed Bycatch Observer Programme. In addition to providing information on marine mammal bycatch 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. The 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 currently takes place on vessels targeting monkfish (*Lophius americanus*) and Greenland halibut (*Reinhardtius hippoglossoides*) (and that is based on the percent of total landed catch that is observed in each directed fishery – time spent fishing was not accounted for). In practical terms, there is only limited opportunity for fisheries observers to board the smallest vessels <35 ft long.

Sentinel Fishery Database

The Sentinel Fishery database consisted of detailed fisheries data collected from the scientifically-managed Sentinel Fishery (n=81 nearshore fishers) (Table 1). This fishery was established in 1995 after the introduction of the groundfish moratoria to enable a continued monitoring of the stocks by fishing under scientifically designed protocols. Vessels involved are almost all smaller than 35 ft, and their effort is relatively low (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 effort for small-boat, nearshore fisheries. Fishers participating in the Sentinel Fishery are contacted every year by the Marine Mammal Section in St. John's to discuss marine mammal bycatches that might have occurred in their gear, and they submit most of these bycaught animals to DFO. These reports were incorporated into the total bycatch estimates for that particular area and period of the year.

Marine Mammal Bycatch Collector Database

The Marine Mammal Bycatch Collector data (n=45 small-boat fishers) consisted of extremely detailed reports on a variety of fisheries. 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 vast majority of catches are made close to the home port. The fishers in this programme were most active in the gillnet fisheries for Atlantic cod, lumpfish (*Cyclopterus lumpus*), and other groundfish (such as winter flounder [*Pseudopleuronectes americanus*]). These fishers were originally selected because they participated in fisheries

that were known to have high catches of seals (e.g., lumpfish fishery). However, small cetaceans, especially harbour porpoise, were reported regularly also.

Deriving Estimates of Small Cetacean Bycatch

Marine mammal bycatch events were recorded through the data collection programmes described above. Rates of bycaught porpoises per unit effort obtained from the Sentinel and bycatch logbooks were extrapolated to the entire fishery based on data from the fish landings database and groundfish log-book data. The units of effort used in these calculations were either kg of landed catch (including catches of the target species as well as other landed bycatch) or number of net-days (number of nets set per day, for the total number of days fished).

In many cases, only landed catch was available as a measure of effort, and we had to estimate the number of net-days of effort for these fishers. These estimates were based on the relationship between landed catch and net-day that were derived from the groundfish logbook database. As such, the total amount of net-days of effort for a given area is based in part on the landed catch information for that area.

When deriving a small cetacean bycatch estimate, catch and bycatch data from Marine Mammal Bycatch Collectors and Sentinel fishers were used to calculate an estimated bycatch rate per kg of landed catch, and per net-day of effort. If effort and bycatch data for more than one fisherman were available in any given NAFO subunit, the bycatch rates were averaged; this generated the estimated bycatch rate for a particular time of year, in this particular area. When landed catch and effort data for the entire fishery for that area and time of year were available, these estimated bycatch rates could be used to calculate an estimate of the total porpoise bycatch for the fishery.

It is recognised that the sample size under consideration is frequently small, and difficult to analyse with conventional statistics (Efron and Tibshirani 1993, Simon 1997). The uncertainty associated with estimates of bycatch 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 the dataset, and can be used with comparatively small samples.

Fish landings records from both Marine Mammal Bycatch collectors and Sentinel fishers were combined. Harbour porpoise bycatch rates were calculated using both total landings of individual fishers and fishing trips of individual fishers as the relevant sampling units. These bycatch rate values were resampled 10,000 times, with replacement. This generated 10,000 averages based on individually-resampled bycatch estimates from all individual fishers. The overall mean, and the upper and lower 95% confidence limits, were then used as bycatch rates (per unit effort), and porpoise bycatch was estimated as described above. To present data summaries, the variances of the point estimates were summed to provide a range (95 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. Alonso, DFO, St. Johns, NL, pers. comm.).

Choosing individual fishers as sampling units resulted in large variability in the bycatch estimates (see Results). After reviewing an earlier draft of this paper, which used fishers as sampling units, members of the 2004 National Marine Mammal Peer Review Committee suggested that we also carry out resampling by "fishing trip". In general, bycatch estimates obtained based on “trips” were less variable than those calculated based on landed catch or net day (see Results). There were many cases where no data were available to estimate bycatch rates for specific areas or periods (as is the case for the majority of fisheries in the province). This was caused primarily by the limited amount of reliable bycatch data that were available for analysis. At the smallest scale of bycatch rates for individual NAFO subunits, only those areas for which catch/effort data were available were used for the bycatch estimation analysis. At larger scales, the average bycatch rate from the same fishery for all relevant NAFO subunits during the same time of year was applied to areas with no bycatch rate data.

Bycatch estimation analyses were performed at various geographical scales, to examine how increased lumping of data at increasing geographic scales (from single NAFO subareas to Newfoundland-wide averages) would influence the estimates. While not possible currently, it would be interesting to stratify the data based on harbour porpoise density, something that cannot be done currently due to a

lack of such fine-scale distribution and abundance information, to determine if there is a strong relationship between porpoise abundance and bycatch rates, or if other factors such as the presence of porpoise (and cod) prey are more important.

Results

Current Nearshore Fishing Effort in Newfoundland

Historically the fishery for Atlantic cod was widespread around Newfoundland, with nearshore and offshore components. Following the commercial collapse of a number of north Atlantic fisheries, the groundfish fishery in Newfoundland changed significantly in scope.

As of 2002, approximately 4,000 fishers were engaged in the Atlantic cod fishery (versus more than twice this number in 1989). This included small-boat, nearshore operations as well as larger vessels capable of going further offshore. In 2002, most cod fishing effort occurred along the south and west coasts of Newfoundland; there is relatively little effort offshore.

Observer coverage for this fishery is low - less than 10% of vessels carry an observer, particularly those smaller than 35 ft (D. Kulka, DFO, St. Johns, NL, pers. comm.) - and this coverage is not related to fishing effort.

Estimated Bycatch Rates for Nearshore Cod Fishers in Newfoundland

Total landed cod catches for 2002 approximate 12,000 metric tonnes. Catches were highest along the South coast where almost 7,000 metric tonnes were caught. Approximately 67% of landed catches occurred in the third quarter of the year.

Generally speaking, formal reports of bycatch of marine mammals are rare in Newfoundland. A total of 64 small cetacean entanglements were reported in 2002 by bycatch collectors, Sentinel fishers, and others. Of these, 52 were confirmed or probable harbour porpoises (see below), and 12 were unidentified small cetaceans (several of these may have been harbour porpoise, but others were probably common dolphins [*Delphinus delphis*] or Atlantic white-sided dolphins [*Lagenorhynchus acutus*]). Of the 64 specimens, 27 were caught by Sentinel fishers, 26 by Bycatch collectors, and 11 by other fishers who were not associated with either programme (Table 1).

Two of the 64 bycatch events did not have a date of capture associated with them. Of the 62 reported cases for which the date of capture could be established, most of the bycatch (n=54; 84%) took place in the first two months of the July-September period (third quarter). Seven (11%) took place in the period of April–June (second quarter), while only three events (5%) took place in the period of October–December (fourth quarter). No bycatch events were reported in the January–March period, when there is also little cod fishing activity. The majority of bycaught cetaceans (44 out of 64; 69%) were confirmed to be harbour porpoise by DFO technicians, who collected the carcasses for further studies. Of these 44 harbour porpoises, 20 originated from the East/Northeast coast, 17 from the South coast, and seven from the West coast (Figure 1). Slightly over half (n=25; 57%) were males.

Fifty-six harbour porpoises were reported to have been captured in set gillnets for cod and other groundfish, which have a 14 cm (5.5 in) mesh size (Table 1). In addition to these animals, three were caught in nets set for monkfish and skate, which have an approximately 30 cm (12 in) mesh size, three in nets set for Greenland halibut, which has a 19 cm (7.5 in) mesh size, and two in lumpfish gillnets, which have a 25 cm (10 in) mesh size.

Bycatch rates, and subsequent bycatch estimates, were calculated for three geographic scales (NAFO subareas, coastlines, and an average for all coastal waters around Newfoundland), and four quarters of the year. Bycatch rates were generally low, with slightly higher rates along the south coast (Tables 2-7). Rates among the NAFO subareas varied greatly, even within the same time period.

During the second quarter of the year, the highest bycatch rates (for both net-days and kg catch, based on both fishers and fishing trips as sampling units) were recorded in 3Psc (Placentia Bay) (0.00485 and 0.00132, and 0.01061 and 0.01163, respectively). For the third quarter, bycatch rates per net day were highest in 4Rd (St. Georges Bay) (0.03074 and 0.02560, based on fishers and fishing trips as

sampling units, respectively). If kg landed catch is used as a measure of effort, bycatch rates were highest in 3Lj (Southern Shore), when based on fishers as sampling units, and in 3Lq, when based on fishing trips as sampling units (0.00203 and 0.00471, respectively). For the fourth quarter, rates were highest in 4Rd (St. Georges Bay) when based on fishers as sampling units for net-days, as well as for net-days and kg landed catch when based on fishing trips as sampling units (0.02892, 0.02526 and 0.05000, respectively). For the fourth quarter, when based on fishers as sampling units for kg landed catch, the highest bycatch rate was found in NAFO subarea 3Kd (White Bay) (Tables 2, 5).

At a larger geographical scale, differences between areas became more apparent. The greatest bycatch rates in the second quarter occurred along the south coast (0.00302 and 0.00080, and 0.00486 and 0.00533, for net-days and kg landed catch, based on fishers and fishing trips as sampling units respectively).

In the third quarter, bycatch per net-day was greatest along the south coast, both when based on fishers as sampling units and based on fishing trips as sampling units (0.00487 and 0.00543, respectively). Bycatch per kg landed catch, based on fishers as sampling units is greatest along the east/northeast coast, and bycatch per kg landed catch, based on fishing trips as sampling units is greatest along the south coast. In the fourth quarter, the bycatch rate per net day based on fishers as sampling units is highest along the west coast (0.00482) and the bycatch rate per kg catch based on fishers as sampling units is greatest along the east/northeast coast. Based on fishing trips as sampling units, this pattern is reversed (bycatch rate per net day is highest along the east/northeast coast (0.00228) and the bycatch rate per kg catch is greatest along the west coast (0.01136)) (Tables 3, 6).

At the island-wide geographical scale, bycatch rates per net day were highest during the third quarter of the year, based on both fishers and fishing trips as sampling units (0.00343 and 0.00240, respectively). However, bycatch rates per kg catch were highest during the second quarter of the year for both based on fishers and fishing trips as sampling units (0.00126 and 0.00349, respectively) (Tables 4, 7).

There are differences between bycatch rates for net-days and kg landed catch, but these are not consistent in magnitude or direction. Bycatch rates estimated using landed catch are much more variable than those obtained using net-days, primarily because of the underlying day-to-day variability in catches of fish, even for individual fishers.

With only 64 reported bycatch events, there are necessarily areas where no bycatch is reported to have occurred in a given quarter, and where therefore the estimated bycatch rates are zero. In the case of the analysis at the NAFO subunit level, there were 68 potential values (four quarters of the year, for 17 different NAFO subunits). Of these 68 values, 16 did not have any fishing effort associated with them (most of these occurred during the first quarter); while six did have an active fishery, but no detailed catch/effort reports were available. Thirty-two of these 68 values were zeroes based on at least one reporting fisher, and fourteen of the 68 values were greater than zero, indicating that bycatch of small cetaceans had occurred. The coastline level of analyses appeared to represent the best balance between adequate sample size for resampling and the proportion of cells that contained no data or zero bycatch.

2002 Small Cetacean Bycatch Estimates for Nearshore Newfoundland

Bycatch estimates were developed for small cetaceans (known to be predominantly harbour porpoise) in the nearshore gillnet Atlantic cod fishery, for 2002 in Newfoundland (Tables 8, 9).

In the nearshore gillnet cod fishery in this period, average annual estimates of bycatch (based on net-days as measures of effort) range from 1,324 (too few data to estimate range) to 2,690 (95 percentile range: 379-6,346) based on fishers as sampling units (Table 8), and from 1,555 (126-3,532) to 2,965 (881-5,605) based on fishing trips as sampling units (Table 9). The average estimates of bycatch (based on kg landed catch as measures of effort) range from 2,723 (too few data to estimate range) to 5,946 (1,540-12,974) based on fishers as sampling units (Table 8), and from 9,559 (248-26,269) to 12,649 (1,412-32,631) based on fishing trips as sampling units (Table 9). Confidence limits were recalculated at each increasing level of geographic scale. Based on recovered carcasses, most of these animals were

likely to be harbour porpoises. These ranges in bycatch values are related to the way we regroup the study areas (subareas separated versus subareas per coast combined).

Bycatch rates, and subsequent bycatch estimates, were calculated for three geographic scales (NAFO subareas, coastlines, and an average of all coastal waters around Newfoundland) and four quarters of the year. The 95% confidence limits were calculated for all geographic scales, for all time periods, though these were not combined on a temporal scale. As shown in Tables 2–9, no cetacean bycatch was reported in the first quarter of 2002. Estimated bycatch (Tables 8 and 9) was lowest when studied at the level of the NAFO subarea (1,324 and 1,518 using net days as the unit of effort, and 2,723 and 9,559 using kg landed catch as the unit of effort, for fishers and fishing trips, respectively). The highest bycatch estimates where derived at the intermediate, or "coastline" scale (2,653 and 2,970 using net days, and 4,521 and 12,649 using kg landed catch, for fishers and fishing trips, respectively). Net days provided lower, and less variable, bycatch estimates than did estimates based on the landed catch data as a proxy for effort.

We performed a bycatch analysis using data for the entire island so we would have three scales of decreasing geographical detail, but increasing sample size (for sample sizes, refer to Tables 2-7). The highest bycatch estimates were produced when we combined all fishers from one "coast" (e.g., south, west, or east/northeast). These "coastal" estimates were higher [both for net-day and kg catch] than 1) when we resampled each individual NAFO unit before adding the resulting estimates together, and 2) when we aggregated data for all fishers for the entire island; thus, sample scale had an effect on our analysis.

In general, bycatch estimates obtained based on effort measures for "trips" (Tables 5 to 7, and 9) were less variable than those calculated based on individual fishers (Tables 2 to 4, and 8).

Discussion

Bycatch of harbour porpoise and other small cetaceans occurs regularly in the gillnet fisheries that are active in the province of Newfoundland and Labrador. Although the nearshore fishery for Atlantic cod has been reduced in effort since the early 1990s, there are still large numbers of fishers who target this species, thereby potentially causing high levels of small cetacean bycatch. Other fisheries have developed since the cod moratoria, such as for monkfish and skate (both use large-mesh gillnets), and these also have the potential for high levels of bycatch (see below).

Estimated Porpoise Bycatch In The Nearshore Atlantic Cod Fishery in 2002

Based on bycatch estimates for net-days per fisherman and per fishing trip, the mean annual small cetacean bycatch for the cod fishery for 2002 is estimated to range from 1,324 to 2,965 small cetaceans, the majority of which are likely to be harbour porpoises (Table 8, 9). If kg landed catch is used, the mean annual bycatch of small cetaceans for this fishery is estimated to range between 2,723 and 12,649 animals, per fisherman and per fishing trip, respectively (Table 8, 9). By comparison, based on a telephone survey of fishers, the last bycatch estimate for harbour porpoises was 2,283 porpoises in all of Newfoundland in 1992 (DFO 2001). The confidence limits around the estimates derived in this study are large, so it is difficult to determine if the 2002 estimates represent a decline or increase in porpoise bycatch since the onset of the moratoria. Further complicating such comparisons is the fact that bycatch reports and fisheries observer coverage are very low or non-existent for fisheries which have the potential to be sources of bycatch mortality for harbour porpoises (e.g., Labrador). It is also unknown whether porpoises or other species of small cetaceans might be at risk of bycatch in the cod gillnets set further offshore, particularly off the south coast (St. Pierre Bank). This area was not covered by the present study, as there were no data from either bycatch collectors or Sentinel fishermen to accurately estimate fishing effort, and it was unclear whether the small cetacean bycatch rate of inshore areas would be the same as on St. Pierre bank.

As a measure of fishing effort, and used as a multiplier to derive bycatch estimates, the data in this study indicate that net days – particularly when used at the level of fishing trip rather than individual fishermen – provides a better metric than landed catch. This is likely because the amount of landed

catch is more variable since it is strongly dependent on biotic and abiotic factors that affect local fish abundance. However, net day effort data are not always available for all areas or years in this study area.

The optimal geographic scale at which to analyse cetacean bycatch data in Newfoundland appears to be at the "coastal" level (e.g., south, west, and east/northeast), or the entire island as a single data grouping. In this study the "coastal" scale 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. Conducting our analyses at the level of "coast" appears to strike a good balance between the variation in bycatch rates as a function of sample size and the likely variability of porpoise distribution that would result in differences in catch rates among fishers. In addition, the missing data for some NAFO subunits make the bycatch estimates at that scale less reliable.

At the smallest geographical scale, bycatch coverage is limited to certain areas and times of year. Further, in many cases there is no information on bycatch available. This may lead to decreased precision in the final bycatch estimates at this scale, because it is unknown whether or not the absence of bycatch reports is the result of absence of porpoises or low sampling effort.

There may be several reasons why there is such variation in bycatch reported among fishers, with some fishers having larger porpoise bycatches than others. Perhaps some fishers are operating in porpoise bycatch "hotspots" where there is an overlap of porpoise and their prey, or simply areas of higher harbour porpoise density. There were not enough data in this study to provide strong evidence of bycatch "hotspots" around Newfoundland, although there is certainly a suggestion of this for St. Mary's Bay and Placentia Bay. If such data were available, it might assist in interpreting our results if we could stratify the study by different areas of harbour porpoise density, (although this would result in a lot of missing values in the analyses matrices). When we compared the number of days required to land a certain weight of cod by those fishers that reported small cetacean bycatch with those that do not, we found that there was no greater effort required to land cod when small cetaceans were also bycaught (Figure 2). This is suggestive 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.

The data analyzed in this study show that bycatch of harbour porpoise is still occurring in (at least) the nearshore Atlantic cod fishery, despite the reduction in the scope of this fishery over the last decade. Whether this level could have a detrimental effect on the Newfoundland porpoise population is unknown until population estimates for this region are derived.

Caveats for Bycatch Estimation, and Means to Improve Bycatch Monitoring in Newfoundland

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

1. Generally, sample sizes are small: in several NAFO subareas fewer than five fishers collected data
2. Bycatch collectors do not always fill in their reporting sheets for all their fishing effort, and some do not send in all their sheets
3. Geographical data for catches from small vessels are often unavailable, and this will be particularly problematic for fishers operating near the margins of several NAFO areas
4. It is unclear to what degree our subsample of fishers used to derive bycatch multipliers could be unrepresentative of the entire fleet (e.g. Sentinel fishers may be fishing in other areas than commercial fishers where there might be a higher density of porpoises)
5. There is only limited opportunity for fisheries observers to board the smallest vessels <35 ft. Unfortunately, this is the largest group of vessels now fishing in Newfoundland, and the one that potentially has the greatest impact on porpoise
6. Inaccurate reporting by fishers may occur due to difficulties in correct cetacean species identification by some fishers, or underreporting. Deploying dedicated observers on every boat has been suggested as a means to improve bycatch reporting. However this is impractical for the Newfoundland groundfish fishery as most vessels are small and the cost of such a programme would be prohibitive. In this study, it is unlikely that these fishers would underreport their bycatches given the skill and motivation of the bycatch collectors (i.e., most have a long working relationship with DFO's Marine Mammals Section)

In recent years, there have been many changes to the gillnet fisheries in Newfoundland and Labrador which may have reduced our ability to monitor bycatch of cetaceans effectively. It is unclear whether the fishers who are currently contributing to the Bycatch Collector programme, represent the fisheries that pose the greatest risk to small cetaceans. For example, the season for the lumpfish fishery, which historically reported harbour porpoise bycatch, was moved to earlier in the spring or restricted in duration; estimated harbour porpoise bycatch is lower in this 2002 fishery as a result. On the other hand, the recently-developed fishery for Monkfish and skate along the southern edge of the Grand Banks appears to suffer high levels of bycatch of pelagic dolphins – particularly the common dolphin. (At present there is only one fisherman in the Bycatch Collector programme who is involved in this fishery.) Bycatch monitoring could be improved through the use of fisheries observers on more vessels (especially those <35 ft), who are given additional training in cetacean identification. Further improvements in data could be achieved through stricter adherence to a requirement that fishers complete their logbooks accurately and submit them following each season.

Baitnets As a Potential Source of Small Cetacean Bycatch

An unrecognised, but important source of bycatch in Newfoundland waters is the fishery for small pelagic fish species such as herring (*Clupea harengus*) and groundfish such as winter flounder for lobster bait; these bait fish are desired prey species for many marine mammals, and any nets designed to catch them may capture seals and porpoises as well. As an initial investigation of this fishery, we interviewed a small number of fishers (n=10) by telephone, and developed the following generalities.

Many lobster fishers catch their own bait when it is available although on the west coast fishers seem to purchase much of their bait from specialised fishers who catch herring with small seine nets. Herring appears to be the preferred type of bait by all lobster fishers interviewed so far. Most lobster fishers use gillnets set in shallow water for either herring or winter flounder.

Bait nets do not appear to represent a potentially dangerous subcategory of net effort for small cetaceans such as the harbour porpoise despite the fact that the fishery for bait is widespread, and there may be many bait nets deployed at any one time. When these fishers were asked about cetacean

bycatch in bait nets, all correspondents indicated that it was likely a rare event, with seals being the most commonly entangled species. There might be several reasons for this:

1. These nets do not catch porpoise (too shallow, wrong time of year, good visibility, small mesh size of herring nets may prevent porpoises from getting entangled)
2. These nets do catch porpoise, but those that get caught fall out of the nets before being brought on board
3. These nets catch porpoise, and fishers do not wish this to be widely known, so they do not report these catches (unlikely since bycatch in other gear is reported)

The Monkfish/Skate Fishery As a Potential Source of Small Cetacean Bycatch

Recently, a fishery that has developed along Newfoundland's south coast has come to our attention due to reports of incidental bycatch of small cetaceans in the large mesh nets used in this fishery.

This monkfish and skate (*Raja* sp.) fishery has been prosecuted over the last five years in fishing sectors 3O and 3Ps, primarily along the shelf edge between 100 and 1000 m, extending from St. Pierre Bank to the western portion of the Tail of the Grand Bank (Figure 3). In 2002, 58 vessels (the majority range between 35 and 50 ft) from various home ports in southern Newfoundland participated in this fishery. Bottom-set gillnets with a mesh size of 12" are deployed from the end of May to the end of September, with the greatest fishing effort taking place in late June to early July. A total landed catch of 3,068,200 kg was reported in 2002, of which approximately 92% consisted of monkfish and skate.

We derived preliminary estimates of incidental catches of small cetaceans based on fisher's log data, bycatch observer data, marine mammal observer data, as well as interviews with a small number of fishers (n=5). In this fishery there may have been between 128 and 1,334 small cetaceans bycaught in 2002 (approximately 5% were harbour porpoises, and 25% were identified as "porpoises"; Lawson et al., unpublished data). Thus this fishery appears to represent a potential problem, and we are continuing to study it to better determine bycatch rates, and improve fishers' identification accuracy for bycaught animals.

The Lumpfish and Greenland Halibut Fisheries As Potential Sources of Small Cetacean Bycatch

The nearshore fisheries for lumpfish and Greenland halibut are currently of local importance, and have recently come under investigation for their possible role in bycatch of small cetaceans. Both of these fisheries employ large-mesh gillnets, in which small cetaceans, primarily harbour porpoise and Atlantic white-sided dolphin, have been reported to be entangled (data from the bycatch database).

The nearshore lumpfish fishery is practiced all around the island of Newfoundland, with the highest catches along the South coast. The lumpfish fishery had been identified as an important source of bycatch in earlier studies (Hood 2001).

The nearshore Greenland halibut fishery is not widespread, but is practiced in areas where sufficiently deep waters exist close to shore, such as in Fortune Bay (3Psb) and off Port aux Choix (4Rb). There have been harbour porpoises reported as bycatch in this fishery, but the depth of the gear may be greater than the usual dive depth for these cetaceans. The magnitude of the bycatch in the Greenland halibut fishery is unknown, due to very poor observer coverage in these areas. Further studies are underway to characterise the extent that these two fisheries may be a bycatch risk for small cetaceans in Newfoundland waters.

Conclusions

Bycatch of small cetaceans, virtually all of which are likely to be harbour porpoise, is still occurring at relatively high levels in several fisheries in Newfoundland despite reduced fishing effort. In the 2002 nearshore gillnet cod fishery alone we estimate (using resampled data) that thousands of small cetaceans were bycaught: 1,324 (too few data to estimate range) to 2,690 (95 percentile range: 379-

6,346), or 1,555 (126-3,532) to 2,965 (881-5,605), based on net days as unit of effort, per fisher and per trip per individual fisher, respectively. If kg landed catch is used as the unit of effort, the total bycatch of small cetaceans for this fishery is estimated to range from 2,723 (too few data to estimate range) to 5,946 (1,540-12,974), or 9,559 (248-26,269) to 12,649 (1,412-32,631) animals (per fisher and per trip per individual fisher, respectively).

Most of these were caught in the third quarter of the year along the south coast, with a lesser amount in the second quarter. The scale of data analysis is very important, as it appears that it will influence results: bycatch estimates were highest, and more precise, at an intermediate geographic scale (our three coastline areas).

Given its lower data variability and fewer assumptions required during analysis, we have greater confidence in the cetacean bycatch estimates based on net days as a measure of effort, during fishing trips (rather than effort per fisher). Thus we conclude that it is most likely that approximately 3,000 harbour porpoises were incidentally caught for the nearshore gillnet fishery in Newfoundland in 2002. The 95 percentile range values around the derived estimates are wide (ranging from 126 to 5,605).

As of yet, the estimated 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 bycatch is also unknown.

Bycatch estimates presented here are preliminary, and will likely change as fisheries data for other years are analysed in more detail and we obtain better bycatch rate estimates through directed interviews with other fishers. Other means to improve the quality of data collected, such as deploying dedicated observers on every boat, are usually unfeasible here; fostering a long-term, trusting relationship with a number of representative fishers appears to be the best strategy to limit underreporting of bycatch.

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Table 1: An overview of the databases used in this study. Those which contained the greatest number of bycatch reports (bycatch collectors and Sentinel fishers) include a small fraction of the Atlantic cod fishing effort described in the larger databases.

Data Source	Number of Fishers	Total Catch (kg)	Fishing Effort (Net-days)	Number of Bycatch Events
Marine Mammal Bycatch Collectors	45	137,552.7	8,972.0	26
Sentinel Fishers	81	165,058.4	11,568.9	27
Bycatch Observers	166	60,256.0	4,412.5	*2* [a]
Logbook Groundfish	960	1,844,704.4	94,487.0	0
Fish Landings for Vessels<35 ft	4,580	9,559,095.4	Unknown	0
Catch/Effort for Vessels ≥35 ft	90	689,220.0	64,380.2	0
			Total Bycatch	**56** [b]

[a] Two porpoise reported by the bycatch observers were not used during analyses as they had no date of capture information.

[b] Captured in set gillnets for cod and other groundfish, which have a 14 cm (5.5 in) mesh size. An additional three porpoise were bycaught in monkfish and skate gear (which has a 30 cm (12 in) mesh size), two in lumpfish gear (with a 25 cm (10 in) mesh size), and three in Greenland halibut ear (with a 19 cm (7.5 in) mesh size), to yield a total of 64 bycatch events.

Table 2: Point and resampled estimates for the rate of small cetacean bycatch in the nearshore cod gillnet fishery for 2002, per NAFO-subarea, based on reported bycatches averaged across each NAFO subarea. The effort estimators used were number of small cetaceans caught per number of net-days and per kg of landed catch, for each fisher.

NAFO Subarea	Quarter	Reporting Fishers	Point Estimate	Resampled Estimate			Point Estimate	Resampled Estimate		
				Rate per Net-day				Rate per Kg Catch		
				Lower 95% CL	Average	Upper 95% CL		Lower 95% CL	Average	Upper 95% CL
3K a	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	no fishery	no fisherv		no fishery		no fishery		no fishery	
	3rd	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3K d	1st	no fishery	no fisherv		no fisherv		no fisherv		no fisherv	
	2nd	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	2	0.01389	0.00000	0.013889	0.00000	0.00481	0.00000	0.004809	0.00000
3K h	1st	no fishery	no fisherv		no fisherv		no fisherv		no fisherv	
	2nd	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3K i	1st	no fishery	no fisherv		no fisherv		no fisherv		no fisherv	
	2nd	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	11	0.002399	0.00000	0.00240	0.00000	0.00029	0.00000	0.00029	0.00000
	4th	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3L a	1st	no fishery	no fisherv		no fisherv		no fisherv		no fisherv	
	2nd	0	no data	no data	no data	no data	no data	no data	no data	no data
	3rd	7	0.00603	0.00000	0.00603	0.00000	0.00017	0.00000	0.00017	0.00000
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3L b	1st	no fishery	no fisherv		no fisherv		no fisherv		no fisherv	
	2nd	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3L f	1st	0	no data		no data		no data		no data	
	2nd	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	6	0.008405	0.00000	0.008405	0.00000	0.00168	0.00000	0.001676	0.00000
	4th	0	no data		no data		no data		no data	
3L j	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	7	0.001082	0.00000	0.00108	0.00000	0.00203	0.00000	0.00203	0.00000
	4th	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

NAFO Subarea	Quarter	Reporting Fishers	Point Estimate	Resampled Estimate			Point Estimate	Resampled Estimate		
				Rate per Net-day				Rate per Kg Catch		
				Lower 95% CL	Average	Upper 95% CL		Lower 95% CL	Average	Upper 95% CL
3L q	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	5	0.019261	0.00000	0.019261	0.00000	0.00147	0.00000	0.00147	0.00000
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3Pn	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	no fishery	no fishery		no fishery		no fishery		no fishery	
	3rd	0	no data		no data		no data		no data	
	4th	no fishery	no fishery		no fishery		no fishery		no fishery	
3Ps a	1st	0	no data		no data		no data		no data	
	2nd	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	0	no data		no data		no data		no data	
3Ps b	1st	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2nd	2	0.00137	0.00000	0.00137	0.00000	0.00023	0.00000	0.00023	0.00000
	3rd	4	0.00066	0.00000	0.00066	0.00000	0.00013	0.00000	0.00013	0.00000
	4th	1	no data		no data		no data		no data	
3Ps c	1st	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2nd	9	0.00485	0.00000	0.004851	0.00000	0.00132	0.00000	0.00132	0.00000
	3rd	14	0.001517	0.00000	0.00153	0.00000	0.00023	0.00000	0.00023	0.00000
	4th	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
4R a	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	10	0.00111	0.00000	0.00111	0.00000	0.00606	0.00000	0.00606	0.00000
	3rd	13	0.001917	0.00000	0.001917	0.00000	0.00036	0.00000	0.00036	0.00000
	4th	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
4R b	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	6	0.00402	0.00000	0.00402	0.00000	0.00006	0.00000	0.00006	0.00000
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
4R c	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
4R d	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	1	0.030738	0.00000	0.03074	0.00000	0.00069	0.00000	0.00069	0.00000

NAFO Subarea	Quarter	Reporting Fishers	Point Estimate	Resampled Estimate			Point Estimate	Resampled Estimate		
				Rate per Net-day				Rate per Kg Catch		
				Lower 95% CL	Average	Upper 95% CL		Lower 95% CL	Average	Upper 95% CL
	4th	1	0.028916	0.00000	0.02892	0.00000	0.00060	0.00000	0.00060	0.00000

Note: "No fishery" indicates that for a given area in a given quarter, no fishing effort was reported at all; "0 reporting fishers" and "no data" indicates that, although a fishery was active in a given area, there were no detailed reports on effort and potential bycatch available (either through Sentinel fishers or Marine Mammal bycatch collectors).

Table 3: Point and resampled estimates for the rate of small cetacean bycatch in the nearshore cod gillnet fishery, per coastline area, based on reported bycatches averaged across relevant NAFO subareas. The effort estimators used were number of small cetaceans caught per number of net-days and per kg of landed catch, for each fisher.

Coastline Area	Quarter	Reporting Fishers	Point Estimate	Resampled Estimate			Point Estimate	Resampled Estimate		
				Rate per Net Day				Rate per Kg Catch		
				Lower 95% CL	Average	Upper 95% CL		Lower 95% CL	Average	Upper 95% CL
East/Northeast Coast	1st	0	no data		no data		no data		no data	
	2nd	25	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	51	0.00281	0.00146	0.00302	0.004844	0.00062	0.00022	0.00068	0.001341
	4th	14	0.00198	0.00000	0.00202	0.00595	0.00069	0.00000	0.00070	0.00206
South Coast	1st	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2nd	16	0.00302	0.00016	0.00303	0.00829	0.00080	0.00003	0.00080	0.00229
	3rd	24	0.00487	0.00060	0.00487	0.01184	0.00046	0.00006	0.00045	0.00110
	4th	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
West Coast	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	18	0.00056	0	0.00056	0	0.00337	0	0.00337	0
	3rd	24	0.00332	0.00034	0.00348	0.00731	0.00024	0.00000	0.00024	0.00066
	4th	6	0.00482	0.00000	0.00482	0.00000	0.00010	0.0000	0.00010	0.0000

Note: "No fishery" indicates that for a given area in a given quarter, no fishing effort was reported at all; "0 reporting fishers" and "no data" indicates that, although a fishery was active in a given area, there were no detailed reports on effort and potential bycatch available (either through Sentinel fishers or Marine Mammal bycatch collectors).

Table 4: Point and resampled estimates for the rate of small cetacean bycatch in the nearshore cod gillnet fishery for 2002, for the entire island of Newfoundland, based on reported bycatches averaged across all NAFO subareas. The effort estimators used were number of small cetaceans caught per number of net-days and per kg of landed catch, for each fisher.

Quarter	Reporting Fishers	Point Estimate	Resampled Estimate			Point Estimate	Resampled Estimate		
			Rate per Net Day				Rate per Kg Catch		
			Lower 95% CL	Average	Upper 95% CL		Lower 95% CL	Average	Upper 95% CL
1st	2	0.00000	0.00000	0.00000	0.00000	0.00000		0.00000	0.00000
2nd	59	0.00104	0.00006	0.00105	0.00279	0.00126		0.00001	0.00125
3rd	99	0.00343	0.00176	0.00342	0.00552	0.00049		0.00020	0.00049
4th	28	0.00202	0.00000	0.00203	0.00508	0.00036		0.00000	0.00036

Table 5: Point and resampled estimates for the rate of small cetacean bycatch in the nearshore cod gillnet fishery for 2002, per NAFO-subunit, based on reported bycatches averaged across each NAFO subarea. The effort estimators used were number of small cetaceans caught per number of net-days and per kg of landed catch, per trip, for each fisher.

NAFO Subarea	Quarter	Reporting Fishers	Point Estimate	Resampled Estimate			Point Estimate	Resampled Estimate		
				Rate per Net-day				Rate per Kg Catch		
				Lower 95% CL	Average	Upper 95% CL		Lower 95% CL	Average	Upper 95% CL
3K a	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	no fishery	no fishery		no fishery		no fishery		no fishery	
	3rd	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3K d	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	2	0.01190	0.00000	0.01203	0.03571	0.00082	0.00000	0.00083	0.00246
3K h	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3K i	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	11	0.00200	0.00000	0.00201	0.00499	0.00046	0.00000	0.00046	0.00135
	4th	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3L a	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	0	no data		no data		no data		no data	
	3rd	7	0.00162	0.00000	0.00161	0.00485	0.00039	0.00000	0.00039	0.00116
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3L b	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3L f	1st	0	no data		no data		no data		no data	
	2nd	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	6	0.00782	0.00243	0.00778	0.01456	0.00232	0.000604	0.002328	0.004651
	4th	0	no data		no data		no data		no data	
3L j	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	7	0.00140	0.00000	0.00139	0.00420	0.00140	0.00000	0.00143	0.00421

NAFO Subarea	Quarter	Reporting Fishers	Point Estimate	Resampled Estimate			Point Estimate	Resampled Estimate		
				Rate per Net-day				Rate per Kg Catch		
				Lower 95% CL	Average	Upper 95% CL		Lower 95% CL	Average	Upper 95% CL
	4th	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3L q	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	5	0.02089	0.00533	0.02097	0.04000	0.00471	0.000462	0.00469	0.01131
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3Pn	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	no fishery	no fishery		no fishery		no fishery		no fishery	
	3rd	0	no data		no data		no data		no data	
	4th	no fishery	no fishery		no fishery		no fishery		no fishery	
3Ps a	1st	0	no data		no data		no data		no data	
	2nd	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	0	no data		no data		no data		no data	
3Ps b	1st	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2nd	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	4	0.00179	0.00000	0.00179	0.00436	0.00047	0.00000	0.00047	0.00109
	4th	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3Ps c	1st	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2nd	9	0.01061	0.00000	0.01059	0.02576	0.01163	0.00000	0.01165	0.03367
	3rd	14	0.00204	0.00022	0.00203	0.00484	0.00026	0.00004	0.00026	0.00055
	4th	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
4R a	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	10	0.00169	0.00000	0.00170	0.00508	0.00847	0.00000	0.00858	0.02542
	3rd	13	0.00208	0.00000	0.00207	0.00623	0.00017	0.00000	0.00017	0.00050
	4th	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
4R b	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	6	0.00292	0.00000	0.00288	0.00667	0.00005	0.00000	0.00005	0.00013
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
4R c	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4th	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
4R d	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

NAFO Subarea	Quarter	Reporting Fishers	Point Estimate	Resampled Estimate			Point Estimate	Resampled Estimate		
				Rate per Net-day				Rate per Kg Catch		
				Lower 95% CL	Average	Upper 95% CL		Lower 95% CL	Average	Upper 95% CL
	3rd	1	0.02560	0.00686	0.02557	0.04846	0.00086	0.00021	0.00086	0.00166
	4th	1	0.025263	0.00000	0.02535	0.07579	0.05000	0.00000	0.05061	0.15000

Note: "No fishery" indicates that for a given area in a given quarter, no fishing effort was reported at all; "0 reporting fishers" and "no data" indicates that, although a fishery was active in a given area, there were no detailed reports on effort and potential bycatch available (either through Sentinel fishers or Marine Mammal bycatch collectors).

Table 6: Point and resampled estimates for the rate of small cetacean bycatch in the nearshore cod gillnet fishery, per coastline area, based on reported bycatches averaged across relevant NAFO subareas. The effort estimators used were number of small cetaceans caught per number of net-days and per kg of landed catch, per trip, for each fisher.

Coastline Area	Quarter	Reporting Fishers	Point Estimate	Resampled Estimate			Point Estimate	Resampled Estimate		
				Rate per Net Day				Rate per Kg Catch		
				Lower 95% CL	Average	Upper 95% CL		Lower 95% CL	Average	Upper 95% CL
East/Northeast Coast	1st	0	no data		no data		no data		no data	
	2nd	25	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3rd	51	0.00184	0.00080	0.00183	0.00301	0.00065	0.00021	0.00065	0.00125
	4th	14	0.00228	0.00000	0.00228	0.00685	0.00046	0.00000	0.00047	0.00139
South Coast	1st	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2nd	16	0.00486	0.00000	0.00486	0.01181	0.00533	0.00000	0.00531	0.01545
	3rd	24	0.00543	0.00218	0.00542	0.00942	0.00114	0.00028	0.00115	0.00252
	4th	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
West Coast	1st	no fishery	no fishery		no fishery		no fishery		no fishery	
	2nd	18	0.00085	0	0.00085	0.00254	0.00424	0	0.00424	0.01271
	3rd	24	0.00087	0.00010	0.00086	0.00192	0.00014	0.00003	0.00014	0.00034
	4th	6	0.00024	0.00010	0.00024	0.00072	0.01136	0.0000	0.01161	0.03409

Note: "No fishery" indicates that for a given area in a given quarter, no fishing effort was reported at all; "0 reporting fishers" and "no data" indicates that, although a fishery was active in a given area, there were no detailed reports on effort and potential bycatch available (either through Sentinel fishers or Marine Mammal bycatch collectors).

Table 7: Point and resampled estimates for the rate of small cetacean bycatch in the nearshore cod gillnet fishery for 2002, for the island of Newfoundland, based on reported bycatches averaged across all NAFO subareas. The effort estimators used were number of small cetaceans caught per number of net-days and per kg of landed catch, per trip, for each fisher.

Quarter	Reporting Fishers	Point Estimate	Resampled Estimate			Point Estimate	Resampled Estimate		
			Rate per Net Day				Rate per Kg Catch		
			Lower 95% CL	Average	Upper 95% CL		Lower 95% CL	Average	Upper 95% CL
1st	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2nd	59	0.00195	0.00017	0.00198	0.00443	0.00349	0.00001	0.00349	0.00859
3rd	99	0.00240	0.00142	0.00240	0.00352	0.00062	0.00029	0.00062	0.00105
4th	28	0.00091	0.00000	0.00091	0.00270	0.00150	0.00000	0.00152	0.00433

Table 8: Point and resampled small cetacean bycatch estimates for the nearshore Newfoundland cod gillnet fishery, for each quarter of 2002, at increasing geographic scale, based on effort with fishers as the sampling units. The effort estimators used were number of small cetaceans caught per number of net days and per kg of landed catch. Ninety-five percent confidence intervals for the resampled bycatch estimates were obtained using data bootstrapped 10,000 times, with replacement.

Study Area		Effort - Net Days			Effort - Kg Landed Catch		
	Quarter	Point Estimate	Resampled Estimate	95% CI[a]	Point Estimate	Resampled Estimate	95% CI[a]
NAFO subareas analysed separately							
	1st	0	0		0	0	
	2nd	284	284		851	851	
	3rd	1038	1038		1867	1867	
	4th	2	2		5	5	
	Total	1324	1324		2723	2723	
NAFO subareas per coast combined							
	1st	0	0	0	0	0	0
	2nd	408	409	22-1120	1024	1023	33-2777
	3rd	2222	2257	357-5164	3263	3351	632-7755
	4th	23	23	0-63	234	237	0-695
	Total	2653	2690	379-6346	4521	4611	665-11227
NAFO subareas for coastal Newfoundland combined							
	1st	0	0	0	0	0	0
	2nd	143	144	8-384	1556	1545	11-4348
	3rd	1793	1792	919-2885	3690	3676	1529-6489
	4th	200	200	0-501	727	725	0-2137
	Total	2135	2136	927-3770	5973	5946	1540-12974

[a] At the lowest geographical scale, numbers were too small to permit resampling for confidence limits.

Note: The non-resampled bycatch rates were similar.

Table 9: Point and resampled small cetacean bycatch estimates for the nearshore Newfoundland cod gillnet fishery, for each quarter of 2002, at increasing geographic scale, based on effort with fishing trips as the sampling units. The effort estimators used were number of small cetaceans caught per number of net-days and per kg of landed catch. Ninety-five percent confidence intervals for the resampled bycatch estimates were obtained using data bootstrapped 10,000 times, with replacement.

Study Area	Quarter	Effort - Net Days			Effort - Kg Landed Catch		
		Point Estimate	Resampled Estimate	95% CI	Point Estimate	Resampled Estimate	95% CI
NAFO subareas analysed separately							
	1st	0	0		0	0	
	2nd	386	386	0-939	6531	6559	0-18964
	3rd	1130	1167	126-2587	2901	2915	248-7052
	4th	2	2	0-6	84	85	0-253
	Total	1518	1555	126-3532	9516	9559	248-26269
NAFO subareas per coast combined							
	1st	0	0		0	0	
	2nd	675	675	0-1640	6426	6393	0-18623
	3rd	2270	2266	881-3901	5416	5433	1412-11587
	4th	24	24	0-64	807	822	0-2421
	Total	2970	2965	881-5605	12649	12649	1412-32631
NAFO subareas for coastal Newfoundland combined							
	1st	0	0		0	0	
	2nd	274	278	0-621	4218	4223	0-10380
	3rd	1299	1300	742-1839	4439	4439	2090-7423
	4th	305	305	0-903	3065	3096	0-8828
	Total	1879	1884	742-3363	11722	11758	2090-26631

Note: The non-resampled bycatch rates were similar.

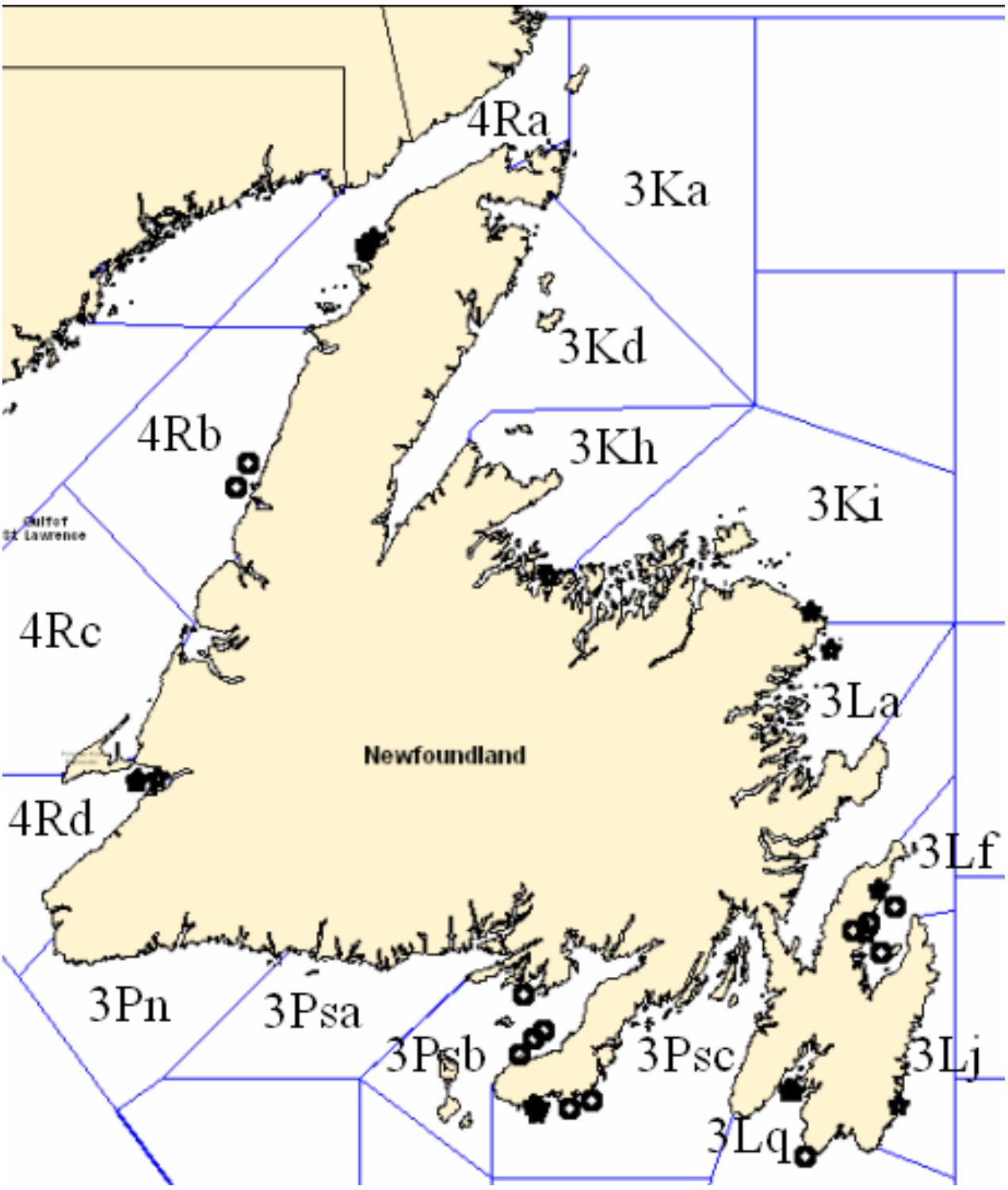

Figure 1. Verified bycatch events involving harbour porpoise in the fixed-gear fishery for Atlantic cod in 2002, for Newfoundland. Stars represent reports from Sentinel fishers, and circles represent reports from Marine Mammal Bycatch collectors. Note that in several cases, repeated captures in the same area lead to overlap of symbols at this geographic scale.

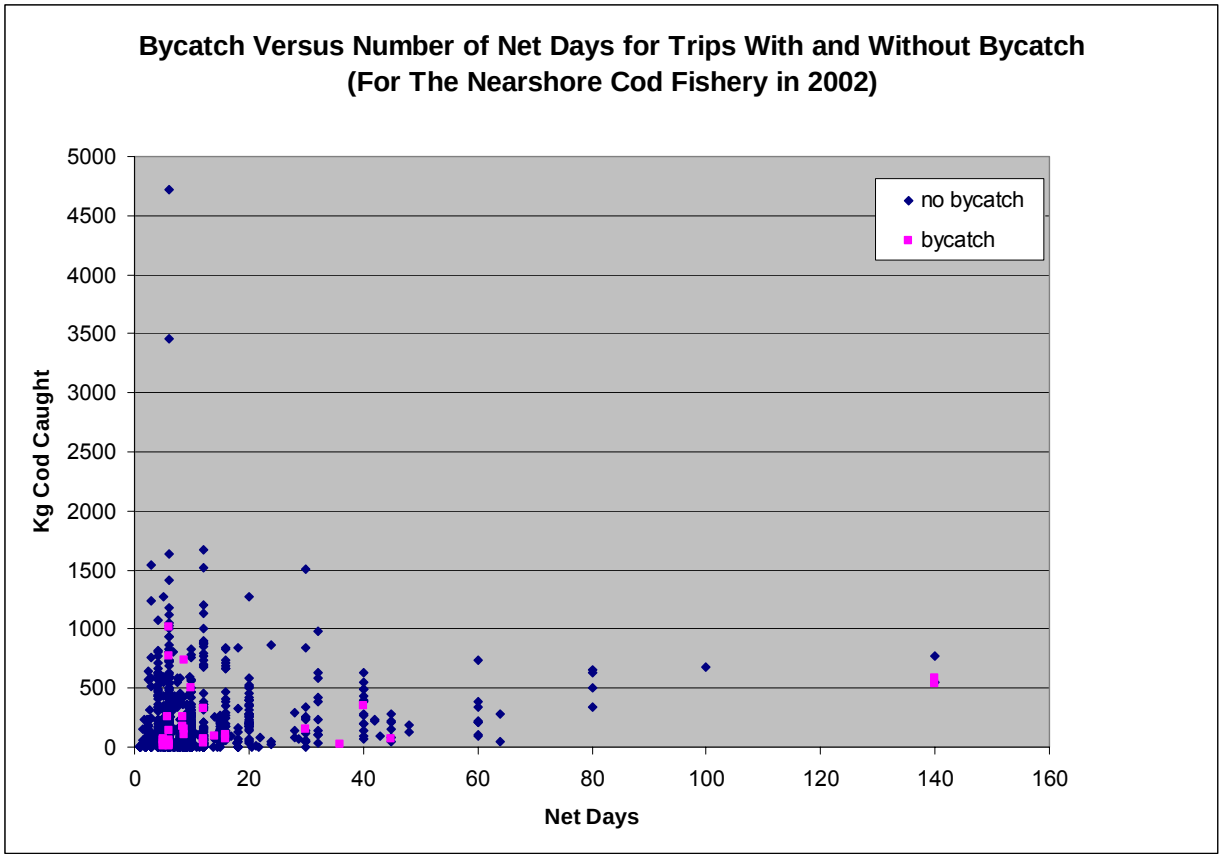

Figure 2: Weight of Atlantic cod caught plotted as a function of the number of net days required to catch it, for fishers with and without small cetacean bycatch, in 2002.

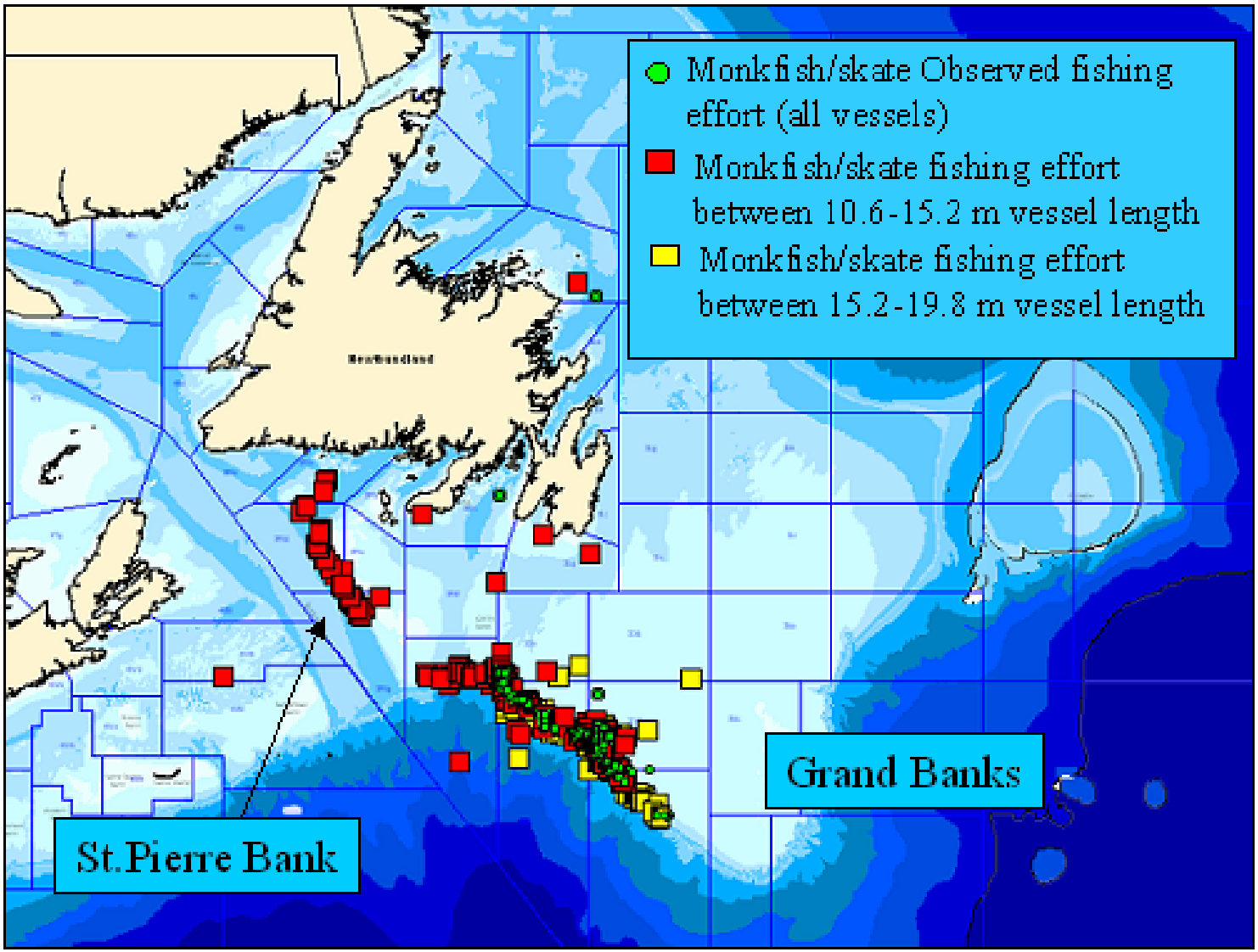

Figure 3: Landed catches and observed fishing effort in the Newfoundland gill-net monkfish and skate fisheries, subdivided by vessel size and NAFO subunit. The total landed catch in 2002 was 3,068,200 kg (91% monkfish and skates). Bycatch observer coverage varied between 4.4% and 75% (based on landed catch).