

Incidental mortality of harbour porpoise (*Phocoena phocoena*) by the gill-net fishery in the lower Bay of Fundy

Edward A. Trippel, John Y. Wang, Michael B. Strong, Lesley S. Carter, and Jeremy D. Conway

Abstract: Mortality of harbour porpoise (*Phocoena phocoena*) as a result of interactions with commercial gill-net fisheries in the Bay of Fundy – Gulf of Maine region has prompted evaluation of the problem and of possible mitigation measures. Observer coverage was made of gill-net vessels in the lower Bay of Fundy, Canada, in 1993 and 1994. Porpoise by-catch rates peaked during August, with 72% of the estimated total by-catch being taken during this month. The two areas characterized by high by-catch spanned 24 and 7 km². This spatiotemporal pattern of by-catch allows for effective mitigation measures without affecting the entire gill-net activity in the Bay of Fundy. The estimated porpoise by-catch in 1993 among the Fundy Isles was 424 ± 224 (mean ± SE), and in 1994 the by-catch was 101 (95% confidence limits 80–122). Uncertainty exists in the 1993 estimate because of low observer coverage and the absence of temporal stratification. Ninety-six percent of captured porpoises were located in the upper two thirds of the 4–5 m high gill nets. When by-catch estimates for the Gulf of Maine were included, the combined by-catch for the entire transboundary population in 1993 was ~1800 porpoises and ranged from 2.7 to 4.3% of total population size.

Résumé : À cause du taux de mortalité des marsouins communs (*Phocoena phocoena*) causé par des interactions avec les pêches commerciales au filet maillant dans la baie de Fundy et le golfe du Maine, on a décidé d'évaluer le problème, ainsi que d'examiner des mesures correctives possibles. En 1993 et 1994, des observateurs ont été chargés de la couverture des bateaux de pêche au filet maillant dans la portion inférieure de la baie de Fundy (Canada). Les prises accessoires de marsouin ont atteint un maximum en août, correspondant à 72% des prises accessoires totales estimées. Les deux zones caractérisées par de fortes prises accessoires avaient des superficies de 24 et de 7 km². Ce profil spatio-temporel des prises accessoires rend possibles des mesures correctives sans répercussions sur l'ensemble des pêches au filet maillant de la baie de Fundy. En 1993, les prises accessoires estimées des marsouins étaient de 424 ± 224 (moyenne ± ET), contre 101 en 1994 (limites de confiance à 95%, 80–122). Les valeurs estimées de 1993 comportent un facteur d'incertitude à cause de la faiblesse de la couverture par les observateurs et de l'absence de stratification temporelle. Quatre-vingt-seize pour cent des marsouins capturés l'ont été dans la portion des deux tiers supérieurs des filets maillants de 4 à 5 m de hauteur. Si l'on rajoute les valeurs estimées des prises accessoires dans le golfe du Maine, les prises accessoires combinées pour toute la population transfrontalière étaient d'environ 1800 marsouins en 1993, ce qui correspond à 2,7–4,3% de l'effectif total. [Traduit par la Rédaction]

Introduction

The harbour porpoise (*Phocoena phocoena*) is captured incidentally throughout its distribution, especially by demersal gill-net fisheries, and these interactions are usually fatal (Gaskin 1984). Many populations across this small cetacean's range have been reported either to be depleted seriously or to have disappeared, probably as a result of interactions with

fisheries (Gaskin 1984, 1992; International Whaling Commission 1991). Interactions between harbour porpoises and gill-net fisheries directed for cod (*Gadus morhua*) and pollock (*Pollachius virens*) are currently of concern in the Bay of Fundy (Fig. 1) and along the New England coast (Bravington and Bisack 1995). Although seasonal coastal movements of harbour porpoises in this region are not completely understood, it is believed that porpoises observed in the lower Bay of Fundy during summer and those found in the Gulf of Maine during other parts of the year belong to the same population (Gaskin 1984). This transboundary population is considered by the Committee of the Status of Endangered Wildlife in Canada to be threatened (Gaskin 1989) and is currently being reviewed by the United States for inclusion under the Endangered Species Act. A potential, though not quantified, threat to the population is the extent of mortalities that occur in demersal gill nets in Canadian waters during summer when a portion of the population inhabits the Bay of Fundy.

The size of the harbour porpoise population in the Bay of Fundy – Gulf of Maine is estimated to be 47 200 (95% CI of 39 500 – 70 600) (Palka 1994, 1995). This is a variance-

Received June 15, 1995. Accepted January 12, 1996.
J12959

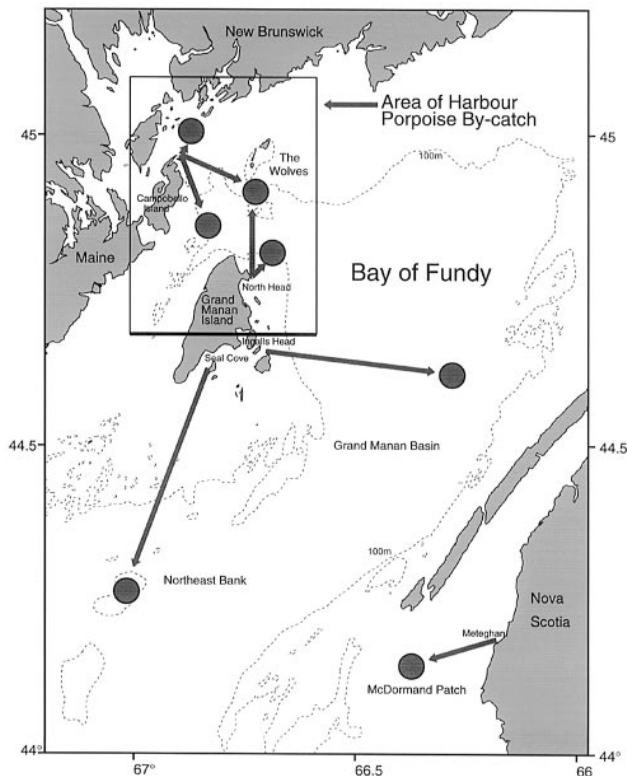
E.A. Trippel¹ and M.B. Strong. Department of Fisheries and Oceans, Biological Station, St. Andrews, NB E0G 2X0, Canada.

J.Y. Wang. Department of Biology, McMaster University, 1280 Main Street West, Hamilton, ON L8S 4K1, Canada.

L.S. Carter and J.D. Conway. Department of Fisheries and Oceans, Resource Management Branch, P.O. Box 550, Halifax, NS B3J 2S7, Canada.

¹ Author to whom all correspondence should be addressed.
e-mail: trippel@wolves.sta.dfo.ca

Fig. 1. The study area showing fishing ports where observers were based and where gill nets were set. The solid lines indicate routes followed by vessels to fishing areas. The boxed area outlines where incidental catches of harbour porpoises in commercial gill nets were observed in 1993 and 1994.



weighted average of the estimates derived in 1991 of 37 500 (95% CI of 26 700 – 86 400) and 1992 of 67 500 (95% CI of 32 900 – 104 600). Even though estimates varied by nearly twofold between the 2 years, they did not differ significantly. Abundance estimates were made during cetacean sighting surveys that were stratified on the basis of water depth and previous knowledge of porpoise densities (Palka 1995).

The U.S. National Marine Fisheries Service monitors the level of harbour porpoise by-catch by sending observers aboard gill-net vessels. The estimated by-catches in the Gulf of Maine fishery in 1990, 1991, 1992, and 1993 were 2900 (95% CI of 1500–5500), 2000 (95% CI of 1000–3800), 1200 (95% CI of 800–1700), and 1400 (95% CI of 1000–2000), respectively (Bravington and Bisack 1995). Observer coverage in the United States ranged from 5 to 10% of fishing effort. Prior to 1993 and 1994, the only by-catch estimates for the gill-net fishery in the lower Bay of Fundy were based on fishers cooperating with researchers in the 1980s. These estimates, based on postseason interviews, ranged from 94 to 116 for 1986 (Read and Gaskin 1988) and 129 for 1987 (Polachek 1989). It is possible that the Bay of Fundy mortalities were underreported.

The objective of this study was to determine the spatial and temporal patterns of harbour porpoise by-catch in demersal gill nets in the lower Bay of Fundy. Information of this kind is required to make decisions regarding possible management measures to reduce by-catch. In 1993, Canada's Department of

Fisheries and Oceans (DFO) initiated a program using on-board observers to estimate possible factors that influence porpoise by-catch rate (i.e., number of porpoises caught per trip made by a commercial gill-net vessel). In 1994, observer coverage was improved and the program focused on providing biweekly estimates of incidental mortalities.

Methods

A random stratified sampling design was used to estimate incidental mortality of harbour porpoise. In 1993, spatial stratification was used, whereas in 1994 because of improved coverage we used both spatial and temporal stratification (i.e., 2-week intervals). The 1993 study was conducted from July 30 to September 10 using 4 observers, and the 1994 study was conducted from July 18 to September 14 using 10 observers. The gill-net fishery was spatially stratified on the basis of fishing port. It was assumed that fishers from each port set their gear in an area distinct from the fishing grounds of fishers from other ports. On the basis of data collected on net locations and discussions with observers and fishers, this assumption was reasonable, although in some instances vessels of different ports accessed the same fishing grounds (Appendix). In these cases, total fishing effort data were prorated according to the portion of trips made to each destination. For each port–destination combination, the mean number of porpoises caught per trip was calculated and multiplied by the number of trips from that port to the destination. The resulting values were summed to produce an estimate of the total number of porpoises caught by the gill-net fishery in the lower Bay of Fundy. Standard errors and 95% CIs were estimated for a random stratified sampling design according to Cochran (1977, pp. 25 and 95, respectively).

Observers were placed as follows. In 1993 and 1994, observers were located at North Head, Grand Manan Island, and on Campobello Island (these islands are in relatively shallow water and coincide with the known spatial distribution of porpoises during summer) (Gaskin 1984). In 1993, to sample more distant offshore gill netting in the Bay of Fundy, observers were placed in two ports on the south end of Grand Manan Island (Ingalls Head, which accesses Grand Manan Basin, and Seal Cove, which accesses Northeast Bank south of Grand Manan Island) and in Meteghan in southwestern Nova Scotia (accesses McDormond Patch) (Fig. 1).

Observer placement in 1993 provided coverage of all southwestern New Brunswick fishing ports that landed gill-netted fish, whereas coverage of Nova Scotia gill-net activity in the Bay of Fundy was limited to vessels departing from Meteghan. Higher coverage was made of New Brunswick vessels as porpoises are known to concentrate on the New Brunswick side of the Bay of Fundy (Gaskin 1984). In 1994, offshore gill-netting activity was only monitored through Seal Cove, Grand Manan Island (coverage from Ingalls Head and Meteghan was ended). Lower sampling of offshore gill-netting occurred in 1994 because no porpoise mortalities were reported from these locations in 1993. This enabled greater coverage of fishing trips from North Head and Campobello Island ports, the only ports where incidental mortalities of porpoises were reported in 1993. The number of trips made by fishers, the number that were accompanied by observers, and the percent observer coverage for 1993 and 1994 are reported in Tables 1 and 2, respectively.

In 1994, a separate investigation was initiated by the Whale Research Group of Memorial University of Newfoundland to examine the effects of acoustic deterrent devices attached to gill nets as a means of reducing by-catch (J. Lien, Memorial University of Newfoundland, St. John's, Nfld., personal communication). The Whale Research Group study was concentrated off North Head, Grand Manan Island, in the Swallowtail area. Use of acoustic deterrents was random throughout the North Head fleet and the daily placement of DFO observers was random (in many cases two observers were present on vessels, one from each study group). The experimental de-

Table 1. Number of vessel trips, number and percentage sampled by observers, harbour porpoise by-catch rate, and estimated porpoise by-catch for vessels from five locations in the lower Bay of Fundy in 1993.

Start port	No. of vessel trips	No. of vessel trips sampled	Percentage of vessel trips sampled	Porpoise by-catch rate (mean \pm SE)	Estimated porpoise by-catch (mean \pm SE)
North Head	119	5	4.2	3.20 \pm 1.74	381 \pm 207
Ingalls Head	133	3	2.3	0	0
Seal Cove	106	14	13.2	0	0
Campobello Island	111	23	20.7	0.39 \pm 0.14	43 \pm 16
Meteghan	79	17	21.5	0	0
Combined total					424 \pm 224

Note: Areas fished from these locations are indicated in Fig. 1 and locations of mortalities are marked in Fig. 3.

Table 2. Number of vessel trips, number of different vessels comprising trips, number and percentage sampled by observers, and estimated porpoise by-catch for vessels from North Head and Seal Cove, Grand Manan Island, and Campobello Island in 1994.

Start port	No. of vessel trips	No. of different vessels comprising trips	No. of vessel trips sampled	Percentage of vessel trips sampled	Estimated porpoise by-catch
North Head, Grand Manan Island					
July 15–31	41	8	6	14.6	20
Aug. 1–15	39	6	21	53.8	22
Aug. 16–31	44	6	23	53.5	20
Sept. 1–15	16	5	7	43.8	3
Total	140		57	40.7	65
Seal Cove, Grand Manan Island					
July 15–31	26	3	4	15.4	0
Aug. 1–15	17	3	12	70.6	0
Aug. 16–31	14	3	5	35.7	0
Sept. 1–15	5	1	5	100.0	0
Total	62		26	41.9	0
Campobello Island					
July 15–31	47	8	25	53.2	2
Aug. 1–15	43	4	24	55.8	11*
Aug. 16–31	39	5	24	61.5	20**
Sept. 1–15	15	5	15	100.0	3
Total	144		88	61.1	36
Combined total					101

Note: The number of observed trips for each of these ports and the associated porpoise by-catch rate are given in the Appendix.

*Two in the channel, two at Head Harbour, others near the Wolves Islands.

**Two at Head Harbour, others near the Wolves Islands.

signs of the two programs were such that further stratification according to sets with or without acoustic deterrents was unnecessary.

In 1993, a single incident of high by-catch occurred on a vessel from the North Head port on August 10. This halted the involvement of North Head fishers for the remainder of the summer (observer coverage from other ports continued). In contrast, full cooperation was received from fishers in 1994.

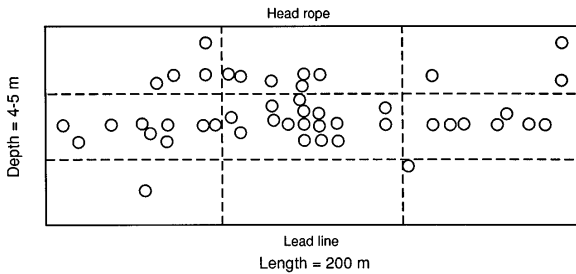
A sampling unit was considered as a vessel's trip. Observers recorded the home port of each vessel, the locations of nets during retrieval, the number of porpoises landed, and the number of porpoises observed that had become disentangled from nets before reaching boats. Porpoise surface drop-out rate was estimated by having observers keep a separate tally of floating porpoises that became disentangled during gear retrieval. Because all observers reported surface drop-outs it was unnecessary to adjust for this mortality component when making by-catch estimates.

Effort data for the period July 15 – September 30 in the form of number of trips made by all gill-net vessels from each port were obtained from DFO's catch and effort statistical system data base with adjustment as required to account for variation in destination as described previously. This spans the period when interactions between

porpoise and gill nets occur in the region (Read and Gaskin 1988). In 1994, the period was shortened to end on September 15 to account for a decline in by-catch rate during late summer (Appendix).

Typically, fishers of each vessel (commonly two fishers in 11- to 14-m vessels) set four to five strings of nets, each of which was made up of three panels (or webs) of monofilament mesh. Each string was about 200 m in length, 4–5 m in height, and 15.2-cm stretched mesh. Nets were retrieved 24–48 h after setting. Because observer coverage was random there was no sampling bias with respect to number of strings set or duration of set. In 1993 and 1994, four Campobello fishers reported their landings once a week, and on these occasions values were expanded to the expected number of trips to be completed in that week (typically three or four on the basis of the frequency of others fishing at that time). An individual fishing trip was considered the best available unit of effort to prorate estimated porpoise by-catch rate. It was not possible to produce estimates of total by-catch based on a given length of gill net, as net length is not recorded in the DFO catch and effort statistical system data base. Landed weight of fish per port was not used to prorate the port-specific by-catch rate, because weight per trip was observed to vary throughout the summer. The amount of fishing gear per trip, however, was observed to remain constant.

Fig. 2. Harbour porpoise by-catch locations ($n = 49$) within a gill-net string plotted from 1994 observer data. Each string was commonly comprised of three webs as shown. Observers noted the approximate net location of each mortality relative to the amount of web retrieved (source: Javitech Ltd., Halifax, N.S.).



Results

From mid-July to mid-September, the total number of trips made by fishers from each port ranged from 79 to 133 in 1993 and from 62 to 144 in 1994 (Tables 1 and 2). In 1993, observers collected data from 62 trips made by 13 fishers and in 1994 from 171 trips made by 16 fishers. Observer coverage of fishing activity at various ports during these periods ranged from 2.3 to 21.5% in 1993 and from 40.7 to 61.1% in 1994 (Tables 1 and 2). In 1993, a total of 25 porpoises were observed caught (16 by vessels from North Head, Grand Manan Island, and 9 by vessels from Campobello Island). In 1994, 49 porpoises were observed caught (26 by vessels from North Head and 23 by vessels from Campobello Island). In 1994, 47 of 49 porpoises were caught in the upper two thirds of the 4–5 m high gill nets. This information was not collected in 1993 (Fig. 2).

Harbour porpoise mortalities were restricted to waters close to the New Brunswick coast among the Fundy Isles (Fig. 3). The majority were caught at the north end of Grand Manan Island in the Swallowtail area and in an area just south of the Wolves Islands approximately 10–15 km north of the Swallowtail area. Locations of mortalities spanned approximately 24 km² at Swallowtail and 7 km² near the Wolves Islands. The spatial distributions of porpoise mortalities were similar between 1993 and 1994 with these two areas being key centres of by-catch (Fig. 3).

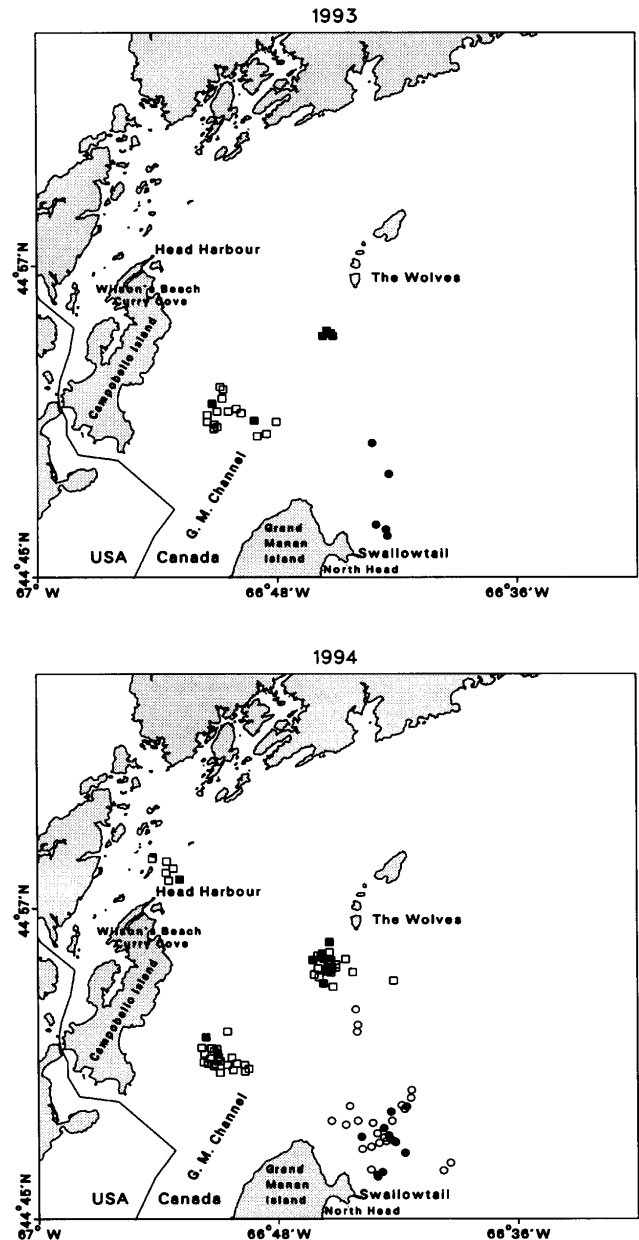
Porpoises were not caught by vessels fishing in the Grand Manan Basin, the Northeast Bank, or on the McDormand Patch (Fig. 1). In 1993 and 1994 a combined 60 observed trips to these offshore areas were conducted without observing a single porpoise mortality (Tables 1 and 2).

By-catch estimates

In 1993, the number of porpoises caught per trip by vessels from North Head was 3.20 ± 1.74 (mean \pm SE) (Table 1). Note that observer coverage was poor at North Head in 1993 as only 5 of a possible 199 trips (or 2.5%) had coverage. Because of low coverage and lack of temporal stratification, the 1993 estimate for North Head should be treated with caution (see Discussion). In 1993, the number of porpoises caught per trip by vessels from Campobello Island was 0.39 ± 0.14 (Table 1).

In 1994, mortalities peaked during August as noted by the mean biweekly catch rates (Appendix, Table 2). In contrast to the single high by-catch in one Swallowtail trip on August 10,

Fig. 3. Inshore regions among the Fundy Isles marking specific locations of harbour porpoise mortalities observed in commercial gill nets in 1993 and 1994 (solid symbols indicate mortalities and open symbols indicate trips with no mortalities). Gill nets set by vessels originating from Grand Manan Island are marked by circles and gill nets from Campobello Island are marked by squares. Because of insufficient data, specific locations of seven trips are not shown for 1994, only one of which resulted in a porpoise mortality. Start port and destination information in the Appendix is complete.



no such incident occurred in 1994. The maximum by-catch for a single vessel trip in 1994 in any area was four porpoises and this occurred in the Swallowtail area (a by-catch of three porpoises occurred there twice).

Annual differences in porpoise by-catch rate occurred. From 1993 to 1994, the mean number of porpoises caught per trip declined for North Head vessels fishing the Swallowtail

Table 3. Estimates of harbour porpoise population size and by-catch for the Gulf of Maine and Bay of Fundy (1986–1994).

Year	Population size	U.S.A.	Canada	Source
1986			105 (94–116) ^a	Read and Gaskin 1988
1987			129	Polacheck 1989
1990		2900 (1500–5500) ^b		Bravington and Bisack 1995
1991	37 500 (26 700 – 86 400)	2000 (1000–3800) ^b		Palka 1994; Bravington and Bisack 1995
1992	67 500 (32 900 –104 600)	1200 (800–1700) ^b		Palka 1994; Bravington and Bisack 1995
1993		1400 (1000–2000) ^b	424 (200–648) ^a	Bravington and Bisack 1995; present study
1994		na	101 (80–122) ^b	Present study

Note: na, not available.

^aRanges are \pm 1SE.

^bRanges are 95% confidence limits.

area. In 1993, the mean value was 3.20, whereas the biweekly 1994 values ranged from 0.50 to 0.61 per trip from July 15 to August 31 and declined to 0.20 per trip in early September (Appendix). The by-catch rate for North Head vessels in 1993 was much greater than the means (0.01 to 0.50 per trip) for the strata in the Gulf of Maine where porpoises were caught (Bravington and Bisack 1995).

In 1993, of the 16 porpoises recorded for North Head vessels, 5 dropped out of nets before they reached the vessels, a 31% drop-out rate. The drop-out rate for Campobello vessels was comparable at 3 of 9 (or 33%). It was not possible to quantify the number of dead porpoises that may have dropped out of nets below the surface.

In 1993, the porpoise by-catch estimate for North Head was 381 ± 207 and for Campobello Island the by-catch estimate was 43 ± 16 (Table 1). The total by-catch estimate for the lower Bay of Fundy in 1993 was 424 ± 224 . The 1994 estimate was approximately 25% of the 1993 estimate. The by-catch estimate in 1994 for North Head was 65 porpoises with 64% of these noted in August (31% from August 15–31) (Table 2). The by-catch estimate in 1994 for Campobello Island was 36 porpoises with 86% of these noted in August (55% from August 15–31). The total by-catch estimate for the lower Bay of Fundy in 1994 was 101 porpoises (95% CI of 80–122) (65 for North Head and 36 for Campobello Island vessels). Thirty-eight of the estimated 101 porpoises captured in 1994 were taken during August 15–31 (Table 2).

Discussion

Harbour porpoise by-catch in the commercial gill-net fisheries in the Bay of Fundy and Gulf of Maine may be summarized as follows: (i) by-catch rates are much higher in the Bay of Fundy than in the Gulf of Maine (Tables 1 and 2; Bravington and Bisack 1995); (ii) total mortality is much lower in the Bay of Fundy because of less fishing effort (Table 3; Bravington and Bisack 1995); (iii) total mortality of ~1800 porpoises by Canada and the United States in 1993 ranged from 2.7 to 4.3% of the estimated population size (Table 3). For management purposes, it is assumed that a discrete population occurs in the Bay of Fundy – Gulf of Maine with limited movement of animals into or out of the area from other parts of the species' range. Recent analysis of mitochondrial DNA of 188 Northwest Atlantic animals provides evidence for this assumption (Rosel 1992; Wang 1993).

The reduction in observed porpoise by-catch in the lower Bay of Fundy between 1993 and 1994 may be due to several

factors: (i) a redistribution of porpoises in the Bay of Fundy and Gulf of Maine, (ii) incorporation of temporal stratification in the 1994 sampling design, and (iii) 1994 experimentation with acoustic deterrent devices on gill nets by J. Lien of Memorial University of Newfoundland, primarily in the North Head area. The random placement of DFO observers on board vessels regardless of acoustic deterrent use, the high coverage, and the estimate by North Head fishers of 55 porpoise mortalities (versus our estimate of 65) in the Swallowtail area (J. Lien and K. Hood, personal communication) indicate that our independent approach to estimate by-catch in 1994 was reasonable.

Potential biases in present estimates

The following biases were corrected between 1993 and 1994 and are important factors to consider when developing a by-catch study.

(i) In 1993, an assumption was made that by-catch rate per port did not vary from July 15 to September 30. Information from Read and Gaskin (1988) and the 1994 study suggest that this is invalid. August appears to be the peak month of porpoise concentration and by-catch. By not adjusting the 1993 by-catch rate for seasonal variation we may have underestimated by-catch for the August portion of the summer but then may have overestimated the by-catch component for the latter half of July and the month of September. Low sampling without temporal stratification strongly influenced estimates of by-catch as inclusion of a single sample raised the by-catch by nearly twofold in 1993 (from 222 to 424 porpoises) and accounts for the high variance associated with this estimate. In 1994, however, improved coverage permitted stratification of catch rate to the biweekly period.

(ii) In 1993, many fishers operating in areas where high by-catches occurred refused to take observers, especially during periods of high porpoise concentration. In 1994, only 2 of 10 fishers in North Head refused observers, though by August 1 there was full cooperation. Incomplete coverage could result in an underestimation of by-catch if those fishers that refused observers set gear in areas with higher by-catch than the remainder of the fleet.

(iii) Even though porpoises were not recorded by observers monitoring vessels fishing in the Grand Manan Basin and on Northeast Bank, it is likely that a few porpoises are taken each year in these areas because porpoises inhabit these waters and have been taken in the past (Read and Gaskin 1988).

(iv) During some trips, poor weather, darkness, or location of the observers on the vessels made it impossible to detect drop-outs at the surface, even near a vessel. Moreover, it is not

unreasonable to suspect that the initial sudden pull, and later constant tension on the nets from hauling anchor lines, would dislodge entangled porpoises below the surface. Onboard observers in the United States who made by-catch estimates noted a surface drop-out rate of 37% (Bravington and Bisack 1995), which is similar to the 31–33% estimates observed in this study.

(v) Although not monitored, some porpoises were likely caught from June 1 – July 15 and in the autumn, though both lower fishing activity and fewer porpoises occur in the region during these periods (Read and Gaskin 1988).

Consequently, our estimation of by-catch is an underestimate of the true value. Nevertheless, these are the first estimates of porpoise by-catch by gill nets set in Canadian waters that were calculated using by-catch rate and fishing effort data. These estimates are presumed to be more representative of the level of annual incidental capture of porpoise in the lower Bay of Fundy than those reported by Read and Gaskin (1988) and Polachek (1989). By-catch encountered in other fisheries in the Bay of Fundy (e.g., weir fisheries) and south of Cape Cod, Massachusetts, have not been included in the present estimates. These additional mortalities are considered to be much lower than those of the Bay of Fundy – Gulf of Maine gill-net fisheries, and efforts are currently underway to enumerate them (A. Read, Duke Marine Laboratory, Duke University, Beaufort, N.C., personal communication). For a complete evaluation of harbour porpoise mortalities in commercial fishing gear, removal by these other sources should be considered. The partial compliance in 1993 followed by full compliance in 1994 might suggest that participation by North Head fishers was conditional on generating a low total by-catch (each observed trip yielded by-catch in 1993; Fig. 3). Consequently, uncertainty remains as to the annual variability in by-catch.

It is noteworthy that a large majority of mortalities in the lower Bay of Fundy occurred in two small geographical areas during August. The gill-net season peaks during the same period when densities of porpoises and other cetaceans are at their highest in the region (Gaskin 1982). It is likely that both porpoises and groundfish such as cod and pollock frequent the area among the Fundy Isles during the summer to prey heavily on large concentrations of herring (*Clupea harengus*) (Recchia and Read 1989). Herring are numerous at this time and support a large weir fishery (Stephenson et al. 1993).

Historical evidence suggests that harbour porpoises may be vulnerable to exploitation; what appeared to be healthy populations in the Baltic Sea and the Black Sea – Sea of Azov have collapsed (Gaskin 1984, 1992). In the Bay of Fundy, there is evidence suggesting that this population may be experiencing overexploitation and showing density-dependent changes; older animals are less prevalent in this population than in the early 1970s (Read and Gaskin 1988), and females are attaining sexual maturity at a younger age and producing larger calves (Read and Gaskin 1990).

The spatial and temporal patterns of by-catch indicate that possible measures to mitigate by-catch need not involve the entire gill-net fleet of the Bay of Fundy. Substantial reduction in by-catch may be achieved by reducing gill-net effort in two relatively small locations among the Fundy Isles during August. An additional management option that is being studied in the Bay of Fundy and elsewhere is to equip gill nets in known areas of high by-catch with acoustic deterrent devices (Kas-

telein et al. 1995), which may serve to reduce by-catch without restricting fishing effort.

Acknowledgements

We thank the individuals who acted as observers for their hard work collecting data on board vessels and the fishers who participated in this program. L. Brown, R. Losier, and B. Best assisted with analyses and preparation of figures. We also thank A.S. Neimanis, J.D. Neilson, D. Bowen, J. Barlow, and an anonymous reviewer for their constructive comments on earlier drafts of the manuscript. This program was supported by the Canadian Department of Fisheries and Oceans and assistance in coordinating the program was provided by the Grand Manan Fisherman's Association, the Campobello Fisherman's Association, the Huntsman Marine Science Centre, Javitech Ltd., and C. Cooper.

References

- Bravington, M.V., and Bisack, K.D. 1995. Estimates of harbour porpoise bycatch in the Gulf of Maine sink gillnet fishery, 1990–1993. Rep. Int. Whaling Comm. **47**: 1–8.
- Cochran, W.C. 1977. Sampling techniques. 3rd ed. John Wiley & Sons, New York.
- Gaskin, D.E. 1982. The ecology of whales and dolphins. Heinemann, London.
- Gaskin, D.E. 1984. The harbour porpoise, *Phocoena phocoena* (L.): regional populations, status, and information on direct and indirect catches. Rep. Int. Whaling Comm. **34**: 569–586.
- Gaskin, D.E. 1992. Status of the harbour porpoise, *Phocoena phocoena*, in Canada. Can. Field-Nat. **106**: 36–54.
- International Whaling Commission. 1991. Report of the sub-committee on small cetaceans. Annex G. Rep. Int. Whaling Comm. **41**: 172–190.
- Kastelein, R.A., Goodson, A.D., Line, J., and de Hann, D. 1995. The effects of acoustic alarms on harbour porpoise (*Phocoena phocoena*) behaviour. In Harbour porpoises: laboratory studies to reduce bycatch. Edited by P.E. Nachtigall, J. Lien, W.W.L. Au, and A.J. Read. DeSpil Publishers, Woerden, The Netherlands. pp. 157–167.
- Palka, D. (Editor). 1994. Results of a scientific workshop to evaluate the status of harbor porpoises (*Phocoena phocoena*) in the western North Atlantic. NOAA/NMFS/NEFSC Ref. Doc. No. 94–09. Northeast Fisheries Science Center, Woods Hole, Mass.
- Palka, D. 1995. Abundance estimate of the Gulf of Maine harbor porpoise. In Biology of the Phocoenids. Edited by A. Bjørge and G.P. Donovan. Rep. Int. Whaling Comm. Spec. Issue No. 16. pp. 27–50.
- Polachek, T. 1989. Harbor porpoises and the gillnet fishery. Oceanus, **32**: 63–70.
- Read, A.J., and Gaskin, D.E. 1988. Incidental catch of harbor porpoises, *Phocoena phocoena*, by gillnets. J. Wildl. Manage. **52**: 517–523.
- Read, A.J., and Gaskin, D.E. 1990. Changes in growth and reproduction of harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. Can. J. Fish. Aquat. Sci. **47**: 2158–2163.
- Recchia, C.A., and Read, A.J. 1989. Stomach contents of harbour porpoise, *Phocoena phocoena* (L.), from the Bay of Fundy. Can. J. Zool. **67**: 2140–2146.
- Rosel, P.E. 1992. Genetic population structure and systematic relationships of some small cetaceans inferred from mitochondrial DNA sequence variation. Ph.D. thesis, University of California, San Diego, Calif.
- Stephenson, R.L., Power, M.J., Sochasky, J.B., Buerkle, U., Fife, F.J.,

and Melvin, G.D. 1993. Biological evaluation of the 1992 4VWX herring fishery. DFO Atl. Fish. Res. Doc. No. 93/76. Department of Fisheries and Oceans, Ottawa, Ont.

Wang, J.Y. 1993. Mitochondrial DNA analysis of the harbour porpoise, *Phocoena phocoena* (L.). M.Sc. thesis, University of Guelph, Guelph, Ont.

Appendix. Harbour porpoise by-catch rates and the number of observed vessel trips (in parentheses) from Grand Manan and Campobello islands in 1994.

Start port	Destination	July 15–31	Aug. 1–15	Aug. 16–31	Sept. 1–15
Grand Manan Island					
North Head	Swallowtail	0.50 (6)	0.55 (20)	0.61 (18)	0.20 (5)
	Wolves Islands		0.00 (1)	0.00 (5)	0.00 (2)
Seal Cove	Northeast Bank	0.00 (4)	0.00 (12)	0.00 (5)	0.00 (5)
Campobello Island					
Curry Cove	Channel	0.00 (9)	0.17 (6)	0.00 (8)	0.00 (4)
Head Harbour	Channel		0.00 (5)	0.00 (2)	0.00 (1)
	Head Harbour	0.00 (3)	0.20 (2)	1.00 (1)	0.00 (2)
	Wolves Islands	0.08 (12)	0.25 (4)	0.57 (7)	0.40 (5)
Wilsons Beach	Channel	0.00 (1)			
	Wolves Islands		0.71 (7)	1.16 (6)	0.00 (3)