Abstract.—We examined 107 harbor porpoise (*Phocoena phocoena*) carcasses recovered from beaches in Maryland, Virginia, and North Carolina between 1994 and 1996 for evidence of entanglement in fishing gear. Stranded porpoises ranged in length from 102 to 128 cm, indicating that only juvenile porpoises are present in the nearshore waters of the Mid-Atlantic during winter. Of the 40 porpoises for which we could establish cause of death, 25 displayed definitive evidence of entanglement in fishing gear. Evidence of entanglement consisted primarily of line marks from nets; in four cases we were able to determine specifically that porpoises had become entangled in monofilament nets. These mortalities demonstrate the need for a directed observer program for coastal gillnet fisheries in the Mid-Atlantic.

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Documenting the bycatch of harbor porpoises, *Phocoena phocoena*, in coastal gillnet fisheries from stranded carcasses

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Large numbers of harbor porpoises (*Phocoena phocoena*) are killed in United States and Canadian commercial fisheries each year. For example, between 1200 and 2900 harbor porpoises were killed annually between 1990 and 1993 in the Gulf of Maine sink gillnet fishery (Bravington and Bisack, 1996). Porpoises from the Gulf of Maine population have also been killed in gillnet fisheries in the Bay of Fundy, where an estimated 424 and 101 porpoises were taken in 1993 and 1994, respectively (Trippel et al., 1996). Efforts are currently underway to reduce mortality in these fisheries by using a variety of mitigation strategies (Resolve[1]).

Harbor porpoises from the Gulf of Maine and Bay of Fundy are believed to constitute a single population (Palka et al., 1996). The population disperses during winter and some individuals move south to the Mid-Atlantic region (defined here as from New York to North Carolina) (Polachek et al., 1995). Strandings of harbor porpoises have been documented as far south as Florida

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[1] Resolve, Inc. 1996. Final draft of the Gulf of Maine/Bay of Fundy harbor porpoise take reduction team take reduction plan. A consensus document prepared by Resolve, Inc., Washington, DC, 33 p.

(Polachek et al., 1995), but the southern limit of the range of the species is generally accepted to be Cape Hatteras, North Carolina (reviewed in Palka et al., 1996). Little is known about the distribution and ecology of this harbor porpoise population in winter; even less is known about interactions with commercial fisheries in the Mid-Atlantic region. Porpoises are taken in a variety of gillnet fisheries in this area (Read, 1994; Read et al., 1996), but to date it has not been possible to determine the full extent or nature of incidental catches in the southern portion of the range of this population. The impact of these incidental takes on the Gulf of Maine and Bay of Fundy population, therefore, is unknown.

Current monitoring efforts for estimating the magnitude of porpoise bycatch in gillnet fisheries in the Mid-Atlantic rely on observers placed aboard commercial fishing vessels operating in this region. The majority of these observed trips take place more than three miles from shore; coverage of nearshore commercial fisheries by observers is extremely limited. An alternative source of information on marine mammal mortality in these nearshore fisheries comes from documentation of recovered stranded carcasses. Here we augment current monitoring programs by reporting observations of stranded harbor porpoises that exhibit evidence of entanglement in the Mid-Atlantic region. Our intent is to provide this information to managers of observer programs, so that they may concentrate efforts in times and areas where entanglements have been documented.

Methods

Porpoises stranded on the beaches of Maryland, North Carolina, and Virginia[2] in 1994, 1995, and 1996 were examined for evidence of entanglement by using the protocol developed by Haley and Read (1993). This protocol is used by personnel in regional stranding networks to assess the carcasses of stranded marine mammals for the presence of physical evidence consistent with entanglement in fishing gear. Physical evidence of entanglement includes impressions of net material in the epidermis, thin lacerations on appendages, and mutilation, including dismemberment and longitudinal cuts along the ventral abdomen into the body cavity (Fig. 1). In general, these observations are indicative of entanglement and death in fishing gear.

Carcasses were examined on the beach by stranding network personnel for fishery interactions and

[2] Carcasses retrieved in New York, New Jersey, and Delaware were not included in this study because comparable data on fisheries interaction were not available for these specimens.

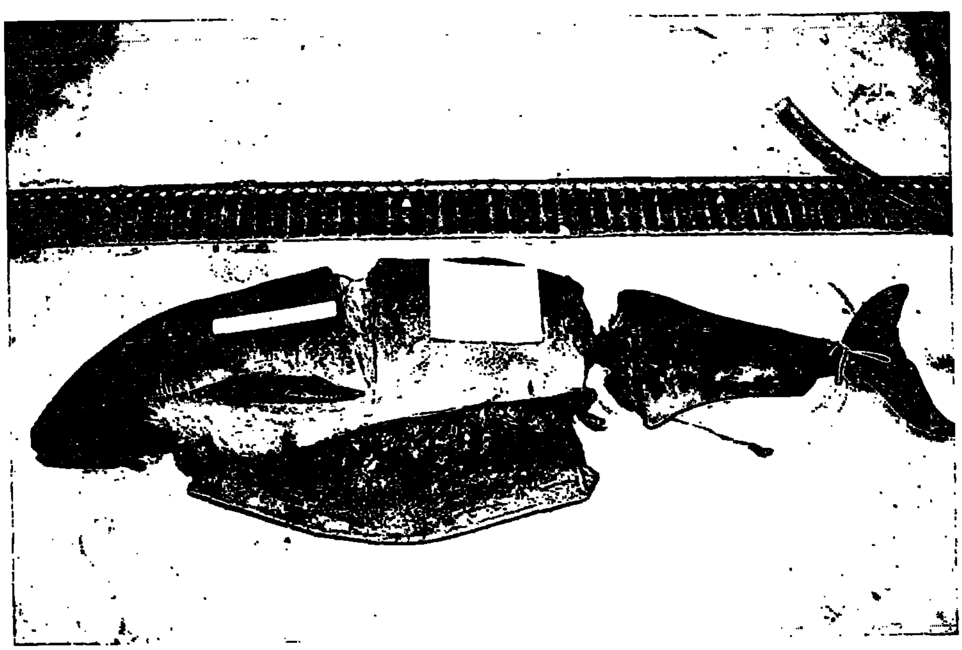

Figure 1

Mutilated carcass of a stranded harbor porpoise, *Phocoena phocoena* (MMSC 94-009). Note the net mark encircling the body just anterior to the insertion of the flipper.

were then stored frozen and examined at the Smithsonian Institution (SI) during necropsy workshops in May 1994, November 1995, and October 1996. In all but three specimens, assessments made by stranding network personnel on the beach were compared with independent assessments made at the SI. The determination of entanglement was conservative; an animal was scored as having been entangled only when external lacerations or impressions from net material or when mutilation consistent with entanglement was clearly present. If a carcass was too decomposed to determine cause of death definitively, or if skin was missing from a large proportion of the appendages, it was scored as "CBD" (could not be determined). Read and Murray[3] determined that all porpoises killed in sink gill nets and retrieved by observers exhibited external net marks. Thus, if a carcass could be assessed, but was scored as not having died of entanglement, the animal was assumed to have died of natural causes. Investigators attempted to identify the net type (i.e. monofilament or multifilament) responsible for the entanglement. The condition of the carcass on the SI scale, in which code 1 = alive, code 2 = dead but fresh, code 3 = moderately decomposed, code 4 = severely decomposed, and code 5 = skeletal remains was noted (Geraci and Lounsbury, 1993).

Standard morphometric data (Norris, 1961) were collected and body condition was evaluated as robust (convex epaxial surface and no "neck" evident) or emaciated (concave epaxial surface and "neck" evident) (Kastelein et al., 1997). Testis size and the presence or absence of ovarian scars (Read and Hohn, 1995) were used to determine the sexual maturity of individuals.

A chi-square test (Sokal and Rohlf, 1981) was used to determine whether there was a difference in carcass condition (SI codes 2 and 3) between entangled and nonentangled animals. To determine if there was a difference in body condition (robust or emaciated) in entangled and nonentangled animals, a G-test with an adjusted G-value for William's correction (Sokal and Rohlf, 1981) was conducted. Two t-tests were also used (Sokal and Rohlf, 1981): the first to compare the mean standard lengths of entangled and nonentangled stranded animals; the second to compare the mean standard lengths of stranded entangled animals and 10 nonstranded entangled animals. The standard lengths of the latter set of porpoises were collected by observers working on gillnet vessels off the coasts of Maryland and North Carolina during 1995 and 1996. Only those animals for which we were able to assess evidence of fisheries interaction were included in the statistical analyses; those scored as CBD were excluded from these analyses. Mean standard lengths are reported with associated standard deviations.

Results

Characterization of strandings

We examined 107 harbor porpoise carcasses (Table 1; Fig. 2). We are aware of 17 additional harbor porpoise strandings that occurred between 1994 and 1996 in the Mid-Atlantic but did not include these strandings in our analysis. Fifteen of these 17 carcasses were not examined according to our protocol, and data discrepancies could not be resolved for two others. Of the 107 porpoise carcasses that we included, 104 were examined independently both on the beach and at SI workshops. The remaining three carcasses were examined only on the beach; however, excellent photo-documentation allowed researchers at the SI to confirm the assessments for these three carcasses that had been made on the beach by stranding network personnel.

All harbor porpoise strandings occurred between January and May, with a peak between the months of March and May (Table 2). Fifty-five animals were male, 51 female; the sex of one was unidentifiable

Table 1

Summary of harbor porpoises (*Phocoena phocoena*) stranded along the Mid-Atlantic coast (by year and state) and evidence of entanglement. Yes = evidence of fisheries interaction; No = no evidence of fisheries interaction; CBD = evidence of fisheries interaction could not be determined owing to advanced decomposition of carcass.

Year	State	Total	Yes	No	CBD
1994	NC	5	0	2	3
	MD	9	4	2	3
	VA	39	13	3	23
	Total	53	17	7	29
1995	NC	7	1	3	3
	MD	2	1	1	0
	VA	15	0	2	13
	Total	24	2	6	16
1996	NC	11	2	2	7
	MD	3	1	0	2
	VA	16	3	0	13
	Total	30	6	2	22
Total		107	25	15	67

[3] Read, A. and K. Murray. 135 Duke Marine Lab Rd., Beaufort, NC 28516. Unpubl. data.

owing to advanced decomposition. The condition of the animals varied: code-3 and code-4 carcasses occurred most frequently in North Carolina and Maryland; the greatest number of code-2 animals was found in Virginia (Table 3; Fig. 3).

We considered 34 animals to be robust and 35 animals emaciated; we could not assess body condition for the remaining 38 animals owing to advanced decomposition. We were able to determine the total standard length of 64 carcasses; 43 were too decomposed to obtain an accurate measurement. Stranded porpoises ranged in length from 102 cm to 128 cm (Mean: 116 ±6 cm; Fig. 4). We were able to assess sexual maturity of 82 porpoises, and all were immature.

Characterization of fishery interactions

Of the 107 carcasses, we found 15 discrepancies between assessments of fishery interaction made by stranding personnel on the beach and those made at the SI workshops. Fourteen of these carcasses were assessed as entangled on the beach, but at the workshops these carcasses were considered too decomposed to evaluate evidence of entanglement. This deteriorated condition likely resulted from decomposition during transport from the beaches to the SI. Before a final assessment was made, we reviewed photographs and records taken at the initial examination of these 14 carcasses. We concluded from this analysis that four of these porpoises died as a result of entanglement (one of these carcasses, for example, had monofilament net wrapped around it when discovered on the beach). Photographs of ten of these carcasses were inconclusive, therefore, to be conservative, we scored them as "CBD." Another carcass was initially scored on the beach as too decomposed for evaluation, but subsequent assessment at the workshop revealed clear signs of entanglement.

Owing to decomposition of the carcasses, only 40 of the 107 porpoises were assessed for signs of entanglement. Of these, a total of 25 (63%) displayed clear evidence of entanglement (Table 1). Entangled

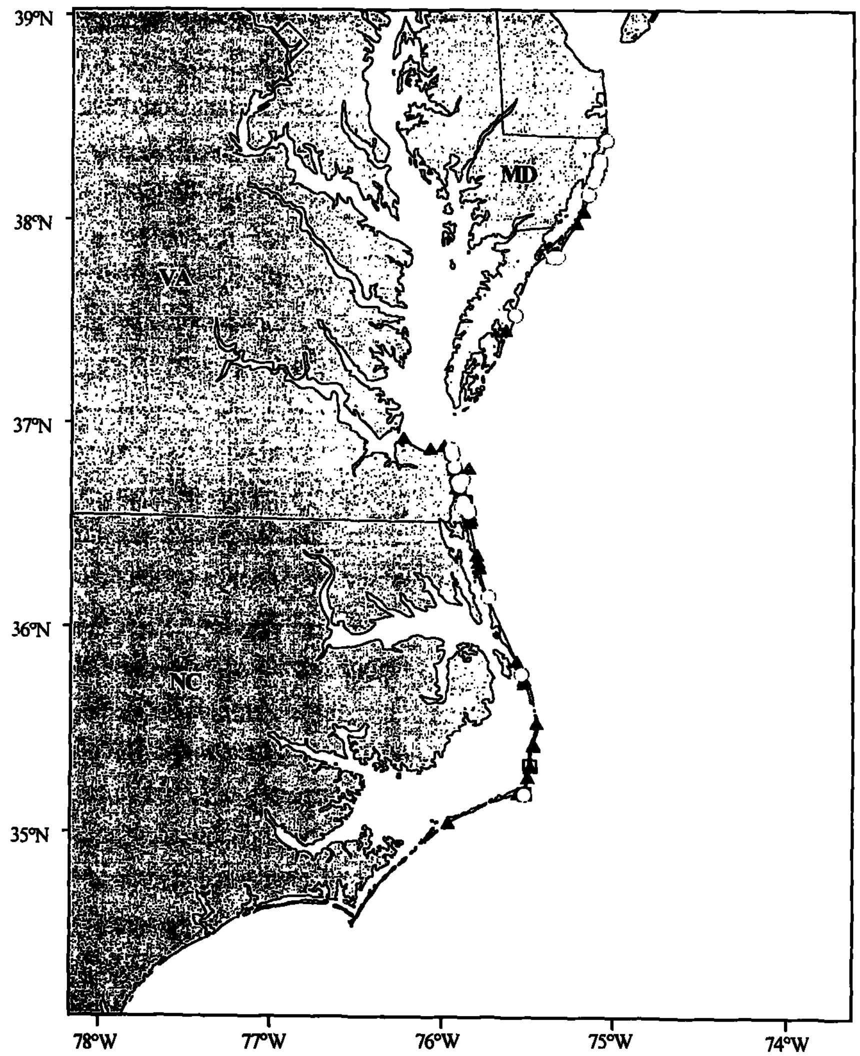

Figure 2

Map of the Mid-Atlantic coast showing stranding locations of harbor porpoises, *Phocoena phocoena*, between 1994 and 1996. Open circle = evidence of fishery interaction; open square = no evidence of fishery interaction; closed triangle = evidence of fishery interaction could not be determined due to advanced decomposition of carcass.

Table 2

Summary of harbor porpoises (*Phocoena phocoena*) stranded along the Mid-Atlantic coast by month. Yes = evidence of fisheries interaction; No = no evidence of fisheries interaction; CBD = evidence of fisheries interaction could not be determined owing to advanced decomposition of carcass.

Month	Yes	No	CBD	Total
January	0	0	1	1
February	2	0	0	2
March	8	7	11	26
April	14	7	39	60
May	1	1	16	18
Total	25	15	67	107

porpoises were observed in all three states between the months of February and May; most (n=13) entangled porpoises were found on the beaches of Virginia (Fig. 2; Table 1) in March and April 1994 (Table 2). Twelve entangled animals were male; 13 were female. We were able to positively identify four cases of entanglement in monofilament gill nets.

Nine of the 25 entangled porpoises were fresh (code 2); 14 were moderately decomposed (code 3); two were very decomposed (code 4). The proportion of code-2 and code-3 porpoises in the sample of entangled porpoises was not significantly different from that of nonentangled animals (χ^2=0.82, df=1, P=0.36). We were able to assess evidence of entanglement for 93% (n=13) of the code-2 animals; 41% (n=24) of the code-3 animals; and 9% (n=3) of the code-4 animals. Fifteen of the entangled animals were robust, and six were emaciated; four were too decomposed to allow us to determine body condition. The proportion of robust animals in the entangled sample was significantly greater than that in the nonentangled sample (G_{adj}=23.51, df=1, P<0.001). None of the entangled animals displayed any unusual gross signs of pathology.

The mean total length of entangled animals was 116 ±5 cm (range: 112–128 cm; Fig. 4). The mean total length of entangled porpoises was not significantly different from that of nonentangled animals (116 ±7 cm; t=0.396, df=36, P=0.69). The mean total length of the entangled stranded animals was significantly less than that of porpoises killed at sea and examined by observers (131 ±14 cm; t=2.97, df=9, P=0.015).

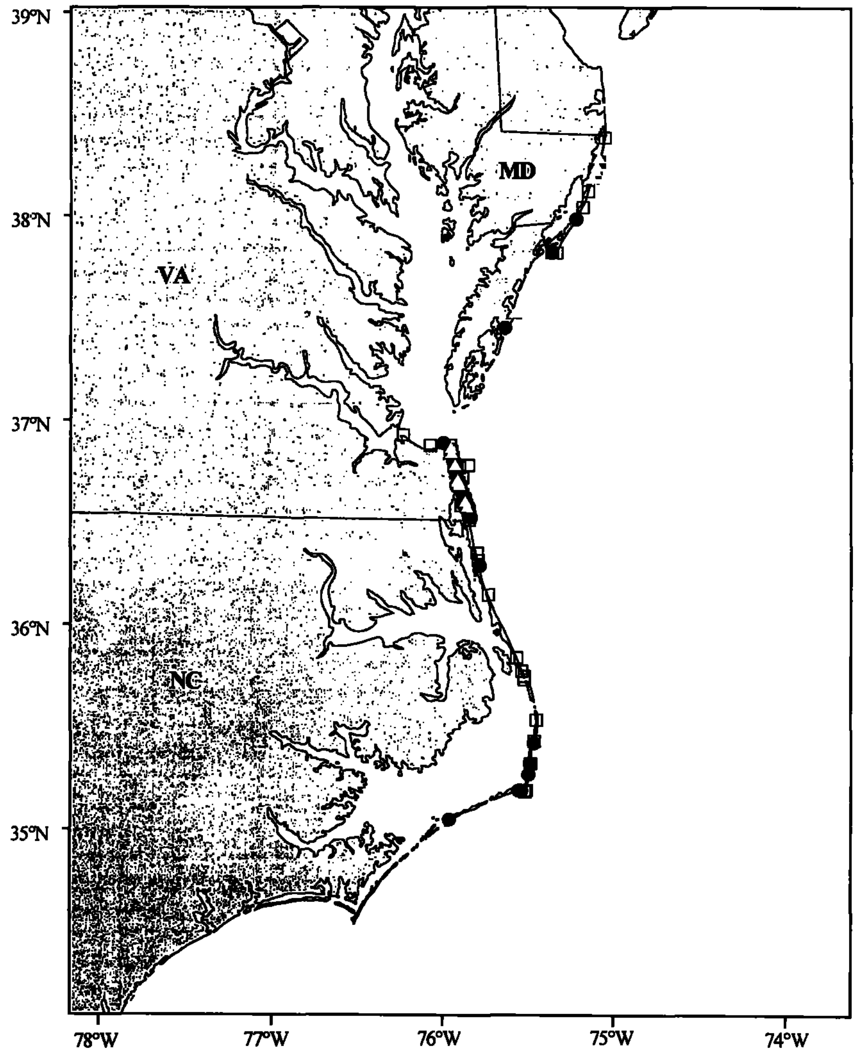

Figure 3

Map of the Mid-Atlantic coast showing stranding locations of harbor porpoises, *Phocoena phocoena*, between 1994 and 1996. Open triangle = SI code 2; open square = SI code 3; closed circle = SI code 4.

Table 3

Summary of Smithsonian Institution codes to define condition of harbor porpoises (*Phocoena phocoena*) stranded along the Mid-Atlantic coast by state. One animal stranded in Virginia was in code-5 condition. Code 1 = alive; code 2 = dead but fresh; code 3 = moderately decomposed; code 4 = severely decomposed; code 5 = only skeletal remains noted.

SI Code	NC	VA	MD	Total
2	0	10	4	14
3	14	37	7	58
4	9	22	3	34
Total	23	69	14	106

Discussion

Here we have documented fisheries mortality in stranded harbor porpoises killed in coastal gill net fisheries in the Mid-Atlantic between 1994 and 1996. However, these deaths represent only an unknown proportion of the total number of porpoises killed in nearshore fisheries along the Mid-Atlantic. Many carcasses were too decomposed to determine cause of death, and our documentation of entanglement was conservative. In addition, it is likely that not all animals entangled in nearshore gill nets reached the beach.

Detailed examination of stranded carcasses can be a useful means of identifying bycatch of harbor porpoises, and other marine mammals, in nearshore gillnet fisheries. This method is not, however, a surrogate for at-sea observer programs that monitor bycatch rates. The gillnet fisheries that operate along the coastal waters of the Mid-Atlantic are diverse, complex, and their activities poorly documented. An observer program is necessary to provide an unbiased estimate of the number of animals killed in these fisheries, so that a complete assessment can be made of this anthropogenic source of mortality.

Accurate assessment of carcasses requires consistent and conservative use of an objective protocol, such as that described by Haley and Read (1993), by trained stranding network personnel. The process of transporting, freezing, and thawing carcasses may obscure subtle evidence of entanglement, so it is important for experienced observers to examine fresh carcasses. At the necropsy workshops, for example, we were unable to assess 14 carcasses that were previously scored as entanglements when examined fresh on the beach.

All stranded porpoises were young and sexually immature. Interestingly, however, both mature and immature porpoises have been taken by gillnet fisheries operating in the Mid-Atlantic. Most of these observed bycatches have been recorded at some distance from shore, suggesting that some age-based segregation occurs in this population during winter. An alternative explanation is that adult porpoises captured in gill nets do not wash ashore. This latter explanation seems unlikely for two reasons. Because of their larger size, carcasses of adults should be more likely to reach shore intact than those of juveniles. In addition, most (17 out of 24) of the observed porpoises taken as bycatch in the Mid-Atlantic were tagged before being discarded; none of these tagged porpoises have subsequently washed up on the beaches. Thus, it appears that only juvenile porpoises are present in the nearshore waters of the Mid-Atlantic during winter.

The proportions of code-2 and code-3 stranded carcasses were not significantly different in the samples of nonentangled and entangled porpoises, indicating that the carcasses of porpoises killed in fisheries were likely originating at similar distances from shore as those animals dying of natural causes. In addition, the lengths of entangled porpoises were similar to those that died from other means. All stranded porpoises, entangled and nonentangled, were from the same segment of the population —young animals in nearshore waters. The distinguishing feature of these two samples is that a larger proportion of the nonentangled animals were emaciated, indicating that they may have died of starvation, whereas most of the entangled animals were in good body condition when they died.

The majority of strandings were reported in Virginia, but this may be due in part to the regular monitoring of beaches in the southern portion of this state. The beaches of Virginia are patrolled frequently by stranding network personnel; therefore stranded porpoises are discovered soon after they appear on the beach. In Maryland beaches are patrolled daily by national and state park personnel. Lower numbers of stranded harbor porpoises in Maryland, therefore, likely reflect lower abundance or different fishing effort and hence fewer strandings in this area. The Outer Banks of North Carolina, by contrast, have not been patrolled frequently, resulting in fewer reports of stranded porpoises. The condition of harbor porpoise carcasses retrieved in North Carolina was poor in relation to those retrieved in

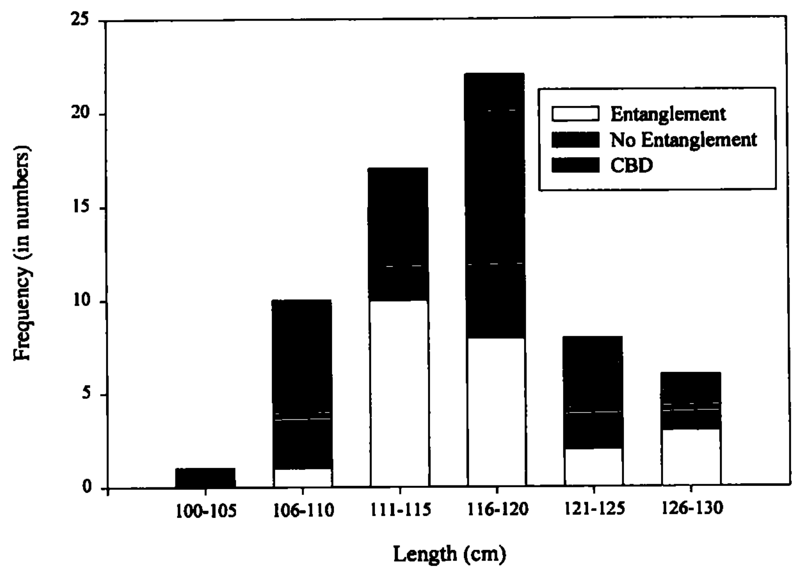

Figure 4

Frequency distribution of the lengths of stranded harbor porpoise, *Phocoena phocoena*, carcasses showing evidence of entanglement, no evidence of entanglement, or carcasses for which evidence of entanglement could not be determined owing to advanced decomposition of the carcass.

Virginia. Harbor porpoises are small animals and are consumed quickly by scavengers. The National Marine Fisheries Service Beaufort Lab and the University of North Carolina at Wilmington are currently increasing the scope and frequency of beach surveys in the Mid-Atlantic to locate carcasses before they are severely decomposed or scavenged.

We were able to identify the type of net involved in the entanglement of only a small number of animals; therefore at present it is not possible to determine the type of gillnet fisheries in which these porpoises were taken. We assume that all entangled animals were caught in gillnet fisheries operating very close to shore, because the carcasses of porpoises captured farther offshore are not likely to reach the beach intact (see above). Although we could not determine in which fisheries the porpoises were entangled, we can draw attention to patterns of fishing activities that correspond to the time and location of strandings. For example, coastal gillnet fisheries for dogfish (*Squalus* spp.) and American shad (*Alosa sapidissima*) are active during March and April in the Mid-Atlantic, corresponding to the period in which most harbor porpoise strandings occur. A large number of entangled animals stranded in Virginia during the spring of 1994, when the coastal fishery for American shad was operating near the Virginia coast. Records from the state of Virginia indicate that 79 licensed watermen, who individually harvested more than 100 lb of American shad, harvested a total of approximately 387,000 lb of American shad in March and April 1994 (Bower[4]). Both the number of licensed watermen who harvested more than 100 lb of shad and the total harvest decreased dramatically in 1995 and 1996 to 50 and 43 licensed watermen and approximately 161,000 and 235,000 lb, respectively (Bower[4]). We noted a corresponding decrease in the number of stranded harbor porpoises in Virginia in the spring of 1995 and 1996 (Table 1).

Here we have attempted to characterize interactions between nearshore gillnet fisheries and juvenile harbor porpoises in the Mid-Atlantic. The bycatch of harbor porpoises in offshore gillnet fisheries in the Mid-Atlantic is currently monitored closely by a National Marine Fisheries Service observer program and thus can be quantified. Unfortunately, the same is not true for harbor porpoise mortality in the coastal gillnet fisheries. There is a need for a directed observer program for nearshore gillnet fisheries in the Mid-Atlantic to better estimate overall mortality of harbor porpoises owing to fishery interactions in this region. Quantifying this mortality will help in management and conservation efforts for harbor porpoises in the Mid-Atlantic.

[4] Bower, D. Virginia Marine Resources Commission, Newport News, VA 23607. Personal commun.

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