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BEACH STRANDINGS AS AN INDICATOR OF AT-SEA MORTALITY OF SEA TURTLES

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ABSTRACT

Estimates of the number of federally protected sea turtles drowned during the 1991–1992 winter trawl fishery for summer flounder off North Carolina were compared to the number of turtles stranded on beaches adjacent to the fishing grounds. The objective was to evaluate how well beach strandings functioned as an indicator of fishery-induced mortality. The number of dead turtles that washed up on the beaches represented a maximum of 7–13% of the estimated fishery-induced mortalities. We attribute this discrepancy to offshore bottom currents, which normally transport lifeless turtles away from the beach during the winter. We conclude that turtle strandings during the winter on the northern beaches of North Carolina are a poor indicator of at-sea mortalities, and that they may not be entirely related to the winter trawl fishery for summer flounder.

Fishing is the most important source of human-associated mortality to all five protected species of sea turtles occurring off the U.S. Atlantic and Gulf coasts (Magnuson et al., 1990). The presence of stressed or dead sea turtles on beaches often is used as an index of at-sea mortalities (Murphy and Hopkins-Murphy, 1989; Magnuson et al., 1990; Caillouet et al., 1991). Of the many factors that can bias the index, wind and currents are perhaps most important, because through their influence dead turtles may be transported some distance before stranding or may never strand. Limited data indicate that the number of stranded sea turtles represents a minimum measure of mortality (Hillestad et al., 1978; Murphy and Hopkins-Murphy, 1989; Renaud et al., 1990, 1991).

The trawl fishery for summer flounder, *Paralichthys dentatus,* has been implicated in several stranding events on the northern beaches of North Carolina (Crouse, 1985; Magnuson et al., 1990). We monitored this fishery in the vicinity of Cape Hatteras, North Carolina during November 1991–February 1992, and found that the incidental catch of sea turtles comprised loggerhead (*Caretta caretta,* 60%), Kemp's ridley (*Lepidochelys kempii,* 36%), green (*Chelonia mydas,* 2%) and hawksbill turtles (*Eretmochelys imbricata,* 1%) (Epperly et al., 1995). An estimated 1,063 turtles were caught during the monitoring period, of which 181 were estimated to be comatose or dead. For strandings to be an unbiased index of at-sea mortalities, beach strandings in the vicinity of Cape Hatteras should mimic the number and species and size composition of mortalities resulting from the fishery. We evaluated this hypothesis by comparing the number of animals stranded on beaches to the estimated number of those taken in the fishery during November 1991–February 1992.

METHODS

Estimates of turtle mortality were derived from at-sea observations during November 1991–February 1992 aboard commercial vessels active in the winter trawl fishery for summer flounder. Observers were present on 6% of the 714 flounder trawling trips reporting landings in Virginia and North Carolina

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Table 1. Estimated total mortality of sea turtles in the summer flounder trawl fishery, November 1991–February 1992. Ranges are given for each estimate based on the assumption that resuscitated turtles all lived or all died. Data from Epperly et al. (1995).

	November–December 1991	January–February 1992	Total
Caretta caretta	66–94	9–17	75–111
Lepidochelys kempii	0–56	0–0	0–56
Eretmochelys imbricata	14–14	0–0	14–14
All species	80–164	9–17	89–181

during the monitoring period. All captured sea turtles were identified and measured (standard measure of over-the-curve carapace length, CCL) by the observers. Total sea turtle catch and mortalities by the fishery were estimated based on a stratified random sampling model (Epperly et al., 1995).

Strandings along the Atlantic and Gulf of Mexico coasts have been reported by volunteers in the Sea Turtle Stranding and Salvage Network (STSSN) since 1980 (Schroeder, 1989). Species, size, location, condition, and final disposition of stressed or dead turtles are recorded. We used STSSN data from ocean beaches between Delaware Bay and Cape Lookout, North Carolina, the geographic range of the summer flounder trawl fishery during fall and winter. Beaches to the north, particularly those of Delaware and the eastern shore of Virginia, were incompletely covered by the STSSN.[2,3] The majority of North Carolina beaches had good coverage.[4]

Results and Discussion

The summer flounder trawl fishery is active from Georges Bank to Cape Lookout, North Carolina. The fishery follows the migrating stock, moving southward over nearshore waters in the fall and northward over deeper waters in the spring (Mid-Atlantic Fishery Management Council, 1988). During the at-sea monitoring period, observers on 42 trips recorded 1058 hauls made between 34°22.8′N and 38°28.2′N (Epperly et al., 1995). During November, fishing activity occurred in the nearshore waters south of Delaware Bay, between 37°49′N and Wimble Shoals (approximately 45 km north of Cape Hatteras). In December, fishing activity generally was split between the Hatteras Bight (the area between Cape Hatteras and Ocracoke Inlet) and the Wimble Shoals–Oregon Inlet area. Some fishing persisted in these nearshore areas through March 1992. By January–February, however, most larger trawlers had moved northward and offshore to the vicinity of Norfolk and Washington Canyons. Based on observed catches, reported number of trips landed, and assumptions about survival of resuscitated turtles, we estimated that 89 (95% C.I. = 22–171)–181 (95% C.I. = 56–342) turtles died as a result of flounder trawl fishing activities during the monitoring period (Epperly et al., 1995) (Table 1). Species composition of the estimated mortalities was 61–84% loggerhead, 0–31% Kemp's ridley, and 8–16% hawksbill turtles. All observed moribund turtles (N = 14) were immature animals. The mean sizes of drowned loggerhead and Kemp's ridley turtles did not differ significantly from the mean sizes of active turtles caught. Moribund loggerheads ranged in size from 45–65 cm CCL and averaged 56 cm (Fig. 1). Moribund Kemp's ridley turtles ranged from 40–52 cm CCL and averaged 48 cm (Fig. 2). The one dead hawksbill turtle was 30 cm CCL. All turtles observed captured during November 1991–February 1992 were caught off the coast of North Carolina (Fig. 3).

Strandings peaked in September–October in Maryland and Virginia, and in October–December on North Carolina beaches north of Cape Lookout (Table 2),

[2] J. A. Keinath, Virginia Institute of Marine Science, Gloucester Point, VA 23602, pers. comm. 19 Nov. 1991.
[3] L. A. Gelvin-Innvaer, Delaware Department of Natural Resources, Dover, DE 19903, pers. comm. 19 Nov. 1991.
[4] T. Henson, North Carolina Division of Wildlife Management, Chocowinity, NC 27817, pers. comm. 28 Oct. 1991.

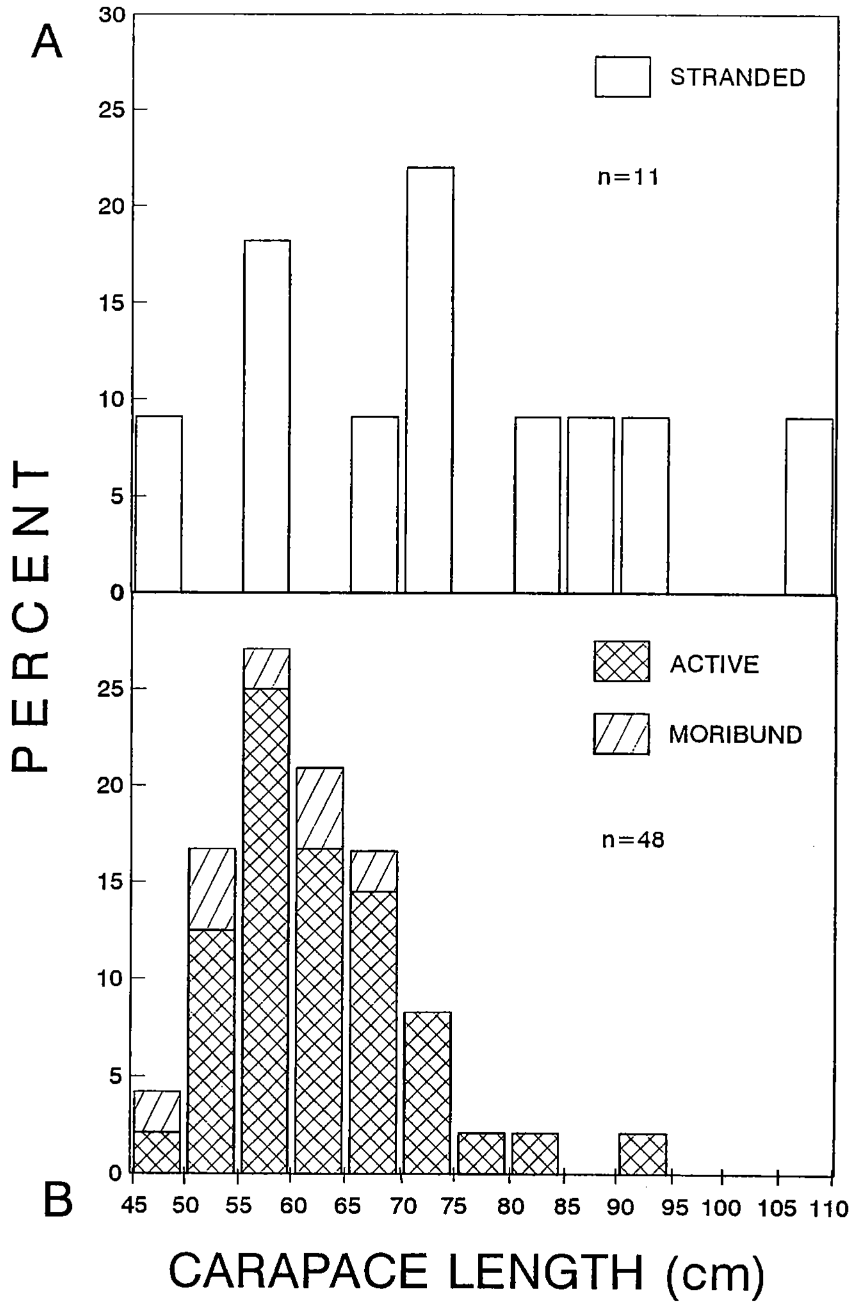

Figure 1. Size distribution of loggerhead sea turtles (*Caretta caretta*), November 1991–February 1992. Carapace measurements were standard measures of over-the-curve length (CCL). A) Turtles stranded between the Virgini a/North Carolina state line and Cape Lookout, North Carolina. Data are from North Carolina Division of Wildlife Management (unpublished) and Sea Turtle Stranding and Salvage Network (National Marine Fisheries Service Miami Laboratory, unpublished data). B) Incidental captures in the trawl fishery for summer flounder. Data are from Epperly et al., 1995.

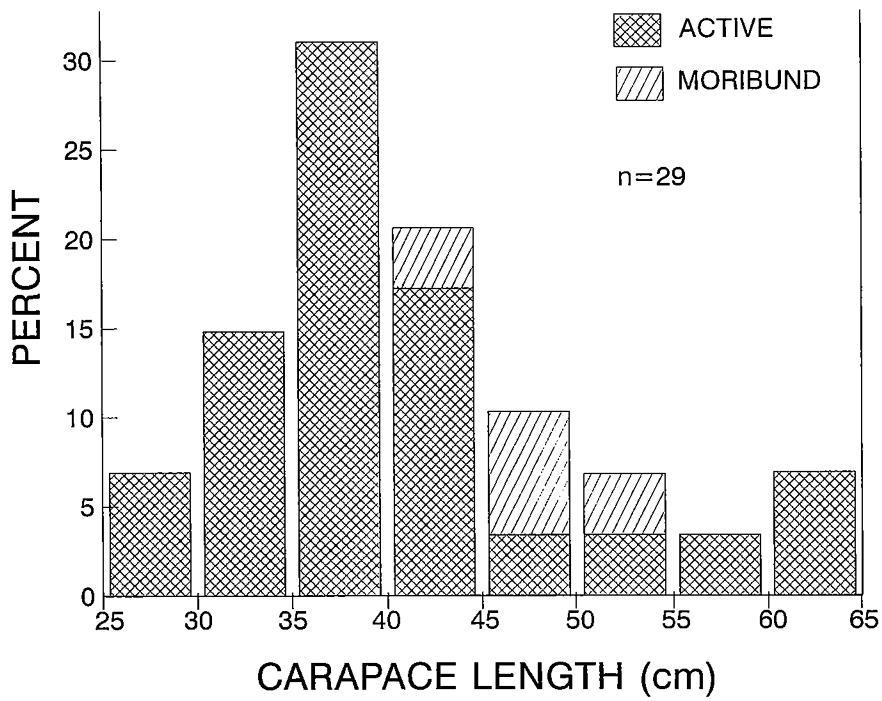

Figure 2. Size distribution of Kemp's ridley sea turtles (*Lepidochelys kempii*) caught in the trawl fishery for summer flounder, November 1991–February 1992. Carapace measurements were standard measures of over-the-curve length (CCL). Data are from Epperly et al. (1995).

coincident with trawling activity for flounder in nearshore waters. One loggerhead stranding in North Carolina during November was spatially disjunct from flounder fishing activity. Thus, 12 North Carolina strandings could have been trawling-related. The loggerhead turtles which stranded in North Carolina averaged 73 cm CCL (range 47–109 cm CCL) (Fig. 1).

The strandings data strongly suggest that not all turtles that died as a result of the summer flounder trawl fishery off North Carolina washed ashore. Although an estimated 89–181 turtles were killed, only 12 strandings were reported on North Carolina beaches that could have been related to trawling activity by the flounder fishery. One turtle was stranded on a Maryland beach and five turtles stranded on Virginia beaches during the monitoring period, but no turtles were observed captured off either state. Assuming all 12 strandings in North Carolina were related to flounder trawling, and excluding the Maryland and Virginia data (we assume Maryland and Virginia strandings were unrelated to trawling, only because we did not observe any mortalities in the catches off these areas), strandings represent just 7–13% of the estimated turtle mortality. Also, there were some discrepancies between the species composition of drowned and stranded turtles. A leatherback (*Dermochelys coriacea*) stranded in North Carolina, although none were observed caught at sea. One dead hawksbill turtle was released at sea, but no hawksbills stranded. Lastly, we would have expected some Kemp's ridleys to have stranded (assuming <100% of the resuscitated turtles survived, Table 1), but none were reported. Kemp's ridleys accounted for 60% of the catch in the Hatteras Bight during November and December, and four were resuscitated (Epperly et al.,

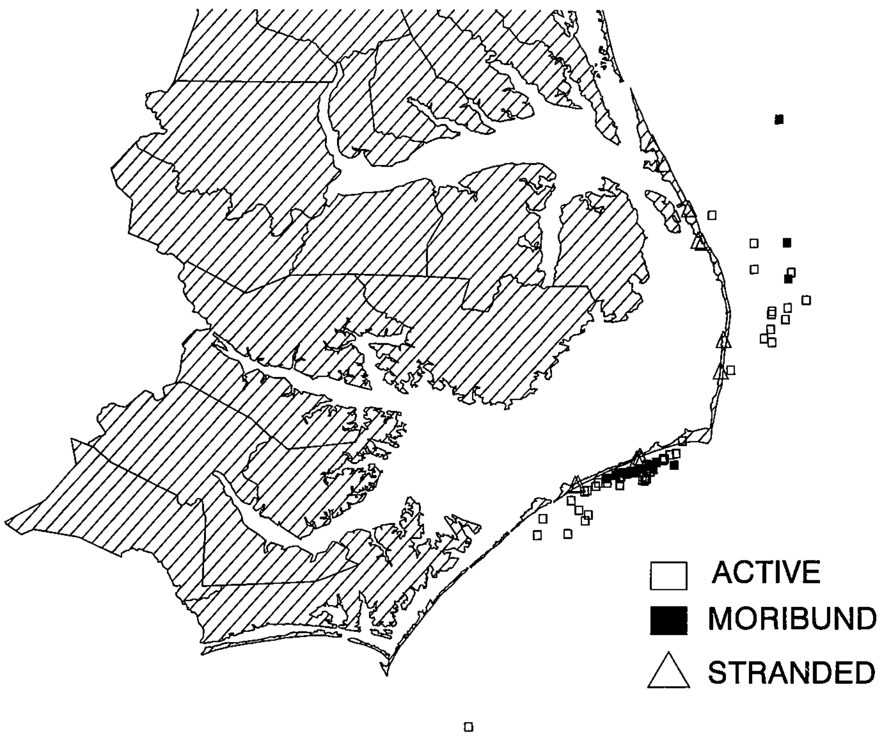

Figure 3. Locations of incidental catches of sea turtles in the summer flounder trawl fishery and turtles stranded on North Carolina ocean beaches north of Cape Lookout, November 1991–February 1992. Stranded turtles are denoted by triangles and incidental captures by squares. Data are from Epperly et al., 1995, North Carolina Division of Wildlife Management (unpublished), and the Sea Turtle Stranding and Salvage Network (National Marine Fisheries Service Miami Laboratory, unpublished data).

Table 2. Sea turtle strandings on ocean beaches from Delaware to Cape Lookout, North Carolina, September 1991–April 1992. Strandings of loggerhead (Cc), Kemp's ridley (Lk), and leatherback (Dc) turtles are noted separately. Data were provided by Delaware Department of Natural Resources, Maryland Department of Natural Resources, Virginia Institute of Marine Science, North Carolina Division of Wildlife Management, and Sea Turtle Stranding and Salvage Network (National Marine Fisheries Service Miami Laboratory).

	State			
Month	Delaware	Maryland	Virginia	N. Carolina
Sep.	0	4Cc	5Cc	1Cc
Oct.	0	3Cc	12Cc, 4Lk	9Cc
Nov.	0	1Cc	4Cc, 1Dc	4Cc, 1Dc
Dec.	0	0	0	7Cc
Jan.	0	0	0	1Cc
Feb.	0	0	0	0
Mar.	0	0	0	2Cc
Apr.	0	0	0	6Cc

1995). One Kemp's ridley with rigor mortis was caught in a trawl; it was dead prior to its capture on that tow.

Juvenile and adult sea turtles have a specific gravity greater than seawater and both adjust their buoyancy by inflating their lungs (Milsom, 1975; Milsom and Johansen, 1975). Consequently, moribund turtles sink to the bottom. As a result of decomposition, the animal will eventually bloat and float to the surface, only to sink again later. Thus, the probability of a moribund turtle beaching in an area is largely dependent upon the near-bottom current field. The discrepancy in number and species composition between beach strandings and at-sea observations could be due to a tendency for offshore bottom flow during the November–February time period. Strong evidence for such a tendency for offshore flow was given by a study in which seabed drifters were deployed over the shelf between 36°07′N and Cape Lookout (Schumacher, 1974; Schumacher and Korgen, 1976). Of the 510 drifters released between November 1972 and February 1973, only 29% were retrieved on the beach. Presumably, most of the remaining 71% were carried offshore. The lowest monthly rate of drifter returns during this period was December (13% north of Cape Hatteras and 19% south of Cape Hatteras). December is also the month of most frequent turtle captures and strandings off northern North Carolina during the winter.

A tendency for offshore near-bottom flow over the North Carolina shelf during late fall and winter is consistent with present knowledge of this region's circulation. Subtidal currents over the inner Carolina shelf appear to be largely due to a mix of wind and buoyancy forcing, whereas subtidal motions over the outer shelf and shelf-edge are predominantly the result of wind forcing and Gulf Stream influences (Atkinson et al., 1980; Chao and Pietrafesa, 1980; Pietrafesa and Janowitz, 1980; Lee and Atkinson, 1983; Lee et al., 1984; Pietrafesa et al., 1985; Lee and Pietrafesa, 1987). While the Gulf Stream induces both seaward and shoreward excursions of water over the Carolina shelf (Lee and Atkinson, 1983; Pietrafesa et al., 1985), it also entrains shelf water at a significant rate (Fisher, 1972; Kupferman and Garfield, 1977; Churchill et al., 1989; Lillibridge et al., 1990) and thus produces a net export of water from the shelf. Wind forcing is likely to result in net seaward drift over the Carolina shelf during November–February, because the winds of this period tend to be from northeast to the northwest (Weber and Blanton, 1980; Weisberg and Pietrafesa, 1983), or favorable for downwelling. Offshore flow also is likely to result from cold air outbreaks during the winter months. These are expected to cool (and thereby increase the density of) shelf water, causing it to cascade to greater depths (Stefansson et al., 1971).

The signal of a satellite tag on a Kemp's ridley sea turtle provides an example of the offshore transport of a turtle carcass during the study period.[5] The turtle was released off Long Island, N.Y. in September 1991 and moved southward. The satellite signal was intermittent, which is consistent with the coincidence of a live turtle surfacing when a receiving satellite was overhead. The signal disappeared for 13 days in November when the turtle was southeast of Cape Hatteras, and then reappeared 500+ km to the northeast as a continuous signal. This indicates the transmitter was constantly at the surface, which is not the behavior of a live turtle. A tenable hypothesis is that the turtle died, sank to the bottom, decomposed, bloated, and floated to the surface. Bottom currents carried it offshore, into the axis of the Gulf Stream where it floated to the surface.

Several major stranding events have occurred during late fall and early winter in the vicinity of trawling activity for flounder (Table 3). Since 1980, an average

[5] S. J. Morreale, Okeanos Research Foundation, Hampton Bays, NY 11946, pers. comm. 19 Dec. 1991.

Table 3. Sea turtle strandings on North Carolina ocean beaches, Cape Lookout to the N.C./Va. state line, November–February, for each fishing season since 1980. Data were provided by the North Carolina Division of Wildlife Management and the Sea Turtle Stranding and Salvage Network (National Marine Fisheries Sevice Miami Laboratory).

	Species					
Fishing season	*Caretta caretta*	*Chelonia mydas*	*Dermochelys coriacea*	*Lepidochelys kempii*	Unknown	Total
1980–81	25					25
1981–82	18			2		20
1982–83	142	2	1	5		150
1983–84	34					34
1984–85	26				1	27
1985–86	39			3	1	43
1986–87	42	1		8	1	52
1987–88	13		1	7	1	22
1988–89	25	3		3		31
1989–90	16	14		1		31
1990–91	65	5		11	5	86
1991–92	12		1			13
1992–93	68	5	1	2		76

of 47 turtles have stranded on North Carolina beaches north of Cape Lookout annually during November-February. Strandings were especially high in 1982–1983 (N = 150), 1990–1991 (N = 86), and 1992–1993 (N = 76). In the largest single event, 144 turtles stranded during November and December 1982, most (N = 88) between Cape Hatteras and Ocracoke Inlet during the first week of December (Crouse, 1985). The cause was not conclusively identified.[6] Trawler captains had reported high catches of turtles during November 1982 off Ocracoke Island; 90% or more were reportedly released alive.[7] In comparison, strandings for 1991–1992 (N = 13), the time period when we estimated 181 turtles were drowned by the flounder fishery, were the lowest on record. Other fisheries operate concurrent with the flounder trawl fishery in the area. Thus, there may be other sources of mortality, and some of the 13 strandings reported during the monitoring period may not have been due to trawling for summer flounder.

Available information indicates that turtles dying over the northern North Carolina shelf during winter will tend to be transported offshore by near-bottom currents. However, as these currents are highly variable (Lee et al., 1984; Pietrafesa et al., 1985), significant annual and intra-annual variation in turtle strandings may be expected. Strandings, therefore, demonstrate only that mortalities have occurred. They are not a reliable indicator, at least during winter months off North Carolina, of the number of mortalities that have occurred. And significantly, the absence of strandings does not imply that at-sea mortality, even of great magnitude, has not occurred.

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[6] D. T. Crouse, Center for Marine Conservation, Washington, D.C. 20036, pers. comm. 18 Nov. 1991.

[7] Memorandum from M. W. Street, North Carolina Division of Marine Fisheries, Morehead City, NC 28557 to D. Crouse, North Carolina Division of Parks and Recreation, Raleigh, NC 27611, 18 Jan. 1983.

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