Sea Turtles in North Carolina Waters

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Abstract: *Until the turn of the century the inshore waters of North Carolina harbored populations of sea turtles large enough to support a commercial fishery. Based on a 4- to-5-year record of sighting reports by the public, interviews of recreational fishermen, and records kept by commercial fishermen the waters continue to provide important developmental habitats for loggerhead, green, and Kemp's ridley sea turtles. Leatherback and hawksbill sea turtles infrequently entered the inshore waters. Reports from the public and commercial fishermen indicated that sea turtles were present offshore North Carolina all year and were present in inshore waters April through December. Sea turtles were encountered most frequently in the Atlantic Ocean, but seasonal encounters in some inshore waters, such as Core and Pamlico Sounds, often were greater. In early May large numbers of leatherbacks were sighted in the ocean and moved northward along the beach. Reported sightings of leatherbacks declined markedly by late June. Based on incidental captures by commercial fishermen loggerhead turtles were the most numerous species in Pamlico and Core Sounds (80%), followed by green (15%) and Kemp's ridley sea turtles (5%). Most captured turtles were immature, and all were released alive. The abundance of immature sea turtles in North Carolina inshore waters serves to emphasize that southeast U.S. estuaries are important habitats for these threatened and endangered species. This recognition supported the decision of the U.S. National Marine Fisheries Service to extend the requirement for turtle excluder devices in shrimp trawls to inshore areas during the entire year; full implementation of these requirements was achieved by December 1994.*

Las tortugas marinas en las aguas de Carolina del Norte

Resumen: *Las aguas costeras de Carolina del Norte (EEUU) acogieron poblaciones de tortugas marinas lo suficientemente grandes como para sostener una pesqueria comercial hasta principios de siglo. Basados en 4 a 5 años de registros de reportes de avistamiento por el público, entrevistas a pescadores deportivos, y registros mantenidos por pescadores comerciales, es posible inferir que las aguas continuan proveyendo importantes hábitats de desarrollo para las tortugas marinas cahuama, verde y lora de Kemp. Las tortugas marinas laúd y de carey entraron en las aguas costeras en forma poco frecuente. Los reportes del público y pescadores comerciales indicaron que las tortugas marinas estaban presentes en las aguas de alta mar frente a las costas de Carolina del Norte todo el año y se encontraban en las aguas costeras entre abril y diciembre. Las tortugas fueron encontradas más frecuentemente en el Océano Atlántico, pero los encuentros estacionales en algunas aguas costeras, tales como los Estrechos de Core y Pamlico, fueron en muchos casos, mayores. A principios de Mayo se avistaron grandes números de tortugas laúd en el oceano las cuales se movían en dirección al norte a lo largo de la costa. Los avistamientos de tortugas laúd reportados declinaron marcadamente hacia finales de Junio. En base a las capturas incidentales por pesqueros comerciales se puede inferir que las tortugas cahuama fue la especie más abundante en los Estrechos de Pamlico y Core (80%), seguidas de las tortugas verdes (15%) y las tortugas loras de Kemp (5%). La mayoría de las tortugas capturadas eran inmaduras y todas fueron liberadas con vida. La abundancia de tortugas marinas inmaduras en las aguas consteras de Carolina del Norte sirven para enfatizar que los estuarios del sudeste de los Estados Unidos son hábitats importantes para estas especies amenazadas y en peligro. Estos reconocimientos fundamentaron la decisión de extender el requerimiento de dispositivos de exclusión de tortugas en la pesca de arrastre del langostino hacia las áreas costeras todo el año; una implementación completa de estos requerimientos fue alcanzada en diciembre de 1994.*

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Introduction

All five species of sea turtles in continental U.S. waters are protected under the Endangered Species Act of 1973 (PL93–205). The results of a population model based on life stages for loggerhead sea turtles (*Caretta caretta*), the most abundant sea turtle in U.S. waters, suggested that reduced juvenile mortality, aided in part by studies on the distribution of immature sea turtles, are necessary for the recovery of loggerhead turtles in U.S. Atlantic waters (Crouse et al. 1987). This conclusion probably is valid for other threatened and endangered sea turtle species as well (Magnuson et al. 1990). Large, immature sea turtles are the type most frequently found dead on ocean beaches (Crouse et al. 1987); shrimp trawling was thought to account for the majority of these deaths. The incidental capture of sea turtles by shrimp trawlers eventually was documented by Henwood and Stuntz (1987), who estimated annual trawler-induced mortality at nearly 11,000. A Congressionally-mandated evaluation of the status of sea turtle populations in U.S. waters confirmed that deaths by shrimp trawls was the largest source of human-associated mortality to sea turtles (as many as 44,000 annually), more than all other sources combined (Magnuson et al. 1990). The study found that most research on sea turtles dealt with nesting animals and that only limited in-water research existed. The authors recommended, therefore, that information be collected on the foraging habitats of sea turtles, including the use of shallow water by immature turtles.

Beginning in the fall of 1987, the National Marine Fisheries Service (NMFS) seasonally required turtle excluder devices (TEDs) in shrimp trawl nets on most boats operating in ocean waters off the southeastern U.S. (Federal Register 1987). Full implementation of the regulations was delayed until 1989 in offshore waters and until 1990 in inshore waters. TEDs incorporate a trap door to allow sea turtles to escape from trawl nets (Seidel & McVea 1982). Boats working in inshore waters were allowed to use tow time limits in lieu of TEDs. The difference between offshore and inshore regulations was due, in part, to the lack of information on the distribution and abundance of sea turtles in inshore waters and to the lack of documentation of incidental captures by shrimp trawlers working in these inshore waters (Federal Register 1992*a*).

The goal of the present study was to investigate the occurrence of sea turtles in North Carolina's inshore waters, particularly the Pamlico-Albemarle Estuarine Complex (Fig. 1). The Complex is the largest estuarine system (6630 km^2) in the southeastern United States and is an important shrimping area, accounting for about 65% of the total inshore shrimp catch in the U.S. Atlantic area (up to 4.2 million kg landed annually; NMFS, unpublished data). Loggerhead and green sea turtles (*Chelonia mydas*) and diamond-back terrapins (*Malaclemys terrapin*) were harvested in North Carolina, mainly from inshore waters (True 1884; Coker 1906; 1951; Rebel 1974), until the turn of the century when stocks became depleted (Pope 1939). Historical data on the status of sea turtles in North Carolina have been summarized by Schwartz (1977*a*, 1977*b*). These authors documented the presence of loggerhead, Kemp's ridley (*Lepidochelys kempii*), and green turtles in inshore waters. They did not provide information on the seasonality, estuarine distribution, or relative species and size composition of the assemblage.

Since the decline of the fishery in the late nineteenth century, no attempt had been made to study sea turtles in the large inshore lagoons of North Carolina. Such a study was needed because of (1) the mandate of the Endangered Species Act to preserve listed species and their habitats; (2) the probability that sea turtles existed in North Carolina inshore waters, based on historical accounts; (3) the need of NMFS to determine the seasonality and distribution of sea turtles in inshore waters (for the formulation of species' recovery strategies); and (4) the presence of a substantial shrimp fishery in North Carolina inshore waters. Our objectives were to determine the species composition of sea turtles and their respective spatiotemporal and size distributions. A secondary objective was to evaluate the utility of various survey methodologies. Because sea turtles are not abundant animals, we attempted to use methods that maximized the amount of time on the water. Herein we describe approaches utilizing public sightings and incidental captures by commercial fishermen. Results of aerial surveys are reported elsewhere (Epperly et al. in press).

Methods

Public Sightings

Two techniques were employed to obtain public sighting data: utilization of the Marine Recreational Fishery Statistics Survey and voluntary reporting by the public. Since 1979, NMFS has sponsored the statistics survey, which consists of interviews of a subsample of recreational anglers fishing in coastal and ocean waters throughout the United States (see Essig et al. 1991). Fishermen are interviewed as they return from the water and are asked to identify the water body where most of their fishing activity occurred; fishermen identifying the ocean are asked if they fished within 5.6 km of shore. Since January 1989, anglers in North Carolina have been asked if they have sighted sea turtles. Beginning in May 1990, they were asked to distinguish between sightings of live and dead turtles (we excluded dead turtles from the analyses). We used the survey data collected from 1989–1992. In a second method of data collection, post-

Figure 1. Coastal counties and water bodies of North Carolina, U.S.

ers bearing franked postcards were widely distributed, and the news media announced our survey project. We asked the public to report all live sea turtle sightings, providing date, location, and species for each sighting. The reports were obtained for 1989–1992. Sightings from both survey methods were partitioned into inshore and Atlantic Ocean areas based on the 72 COLREGS Demarcation Lines, imaginary lines depicted on nautical charts to define where inland versus international regulations are applicable (U.S. Coast Guard 1990). Atlantic Ocean data collected in the statistics survey were further partitioned into nearshore (territorial sea; 0–5.6 km) and offshore (Exclusive Economic Zone; >5.6 km) areas.

Biological Sampling

A limited number of commercial fishermen from Core Sound and eastern Pamlico Sound (Fig. 1) were trained to identify and tag sea turtles and were issued Endangered Species Permits. Initially they recorded incidental captures on provided forms. In later years they were contacted regularly by phone to report all captures since a previous call; infrequently they could provide only estimates of their past catches. As time allowed, they measured, double-tagged (National Band & Tag Company, style Inconel 1005681), and photographed turtles before releasing them. Carapace measurements were standard measures of over-the-curve length

(OCCL). Most of the cooperating fishermen used pound nets (20-cm mesh leads), a passive gear that allows turtles to feed and surface. Fishing operations began in late May behind Hatteras Island in Pamlico Sound, but the full complement of nets was not in place until June. Core Sound operations began in September, with effort concentrated in October–November. Pound-net operations in both areas ended by late December. Some fishermen were involved in other fishing operations throughout the year and reported incidental captures from those activities as well. Data were collected from June 1988 through December 1992.

Reliability and Application of the Data

We considered data provided by commercial fishermen to be very reliable. Each was trained to identify and measure their incidental catches, and initially their identifications were corroborated by photographs of the animals. Tagging allowed us to identify previously recorded animals and their movements, but not all animals were tagged. Thus, some turtles may have been caught and counted more than once. These data were used to determine the species and size composition of sea turtles in inshore waters. Then the data were used to infer seasonal patterns of occurrence within the sounds.

We did not consider species identifications by the public to be reliable, unless the identifications were documented by photography. Leatherbacks (*Dermochelys coriacea*) were an exception, which we assumed the public could identify. Hence, we have not reported public sighting data by species, except for leatherbacks. Statistical survey respondents did not report species identifications. We did consider sighting data reliable, but only in the sense that the sea turtles reported actually had been sighted. The same turtle could have been reported by more than one respondent. Public sighting and statistical survey data were used to describe the seasonal occurrence of sea turtles. Statistical survey data were also used to examine the relative abundance of sea turtles in specific water bodies.

Results

Public Sightings

The Marine Recreational Fishery Statistics Survey in North Carolina queried 10,890 anglers in 1989, 10,898 in 1990, 15,569 in 1991, and 12,876 in 1992, representing a total of about 240,000 hours of fishing activity. About 3% of the anglers reported sighting at least one live sea turtle (Table 1). Live sightings represented 88% of all turtles reported since May 1990.

Sightings of live turtles in the Atlantic Ocean, reported during statistical survey interviews, occurred throughout the year; inshore sightings were reported from April through November (Table 1). Two seasonal peaks were noted in ocean sightings: spring (April–June) along the entire coast, and late fall and early winter (October–December) off the northern coast (Table 2). Generally, turtle sightings in the ocean were greatest

Table 1. Sea turtles sighted by recreational fishermen interviewed in North Carolina during the Marine Recreational Fishery Statistics Survey, 1989–1992.*

Water Body	Mean Hours Fished per Trip	Sightings						
		Jan–Feb	Mar–Apr	May–Jun	Jul–Aug	Sep–Oct	Nov–Dec	All Months
Atlantic Ocean	5.0	0.6 (347)	2.1 (3125)	6.5 (10182)	3.1 (10821)	2.7 (9951)	2.6 (4534)	3.7 (38960)
Albemarle & Currituck Sounds	4.9		0.0 (5)	2.9 (68)	1.6 (125)	0.0 (23)	0.0 (10)	1.7 (231)
Croatan Sound	3.3			0.0 (14)	0.0 (3)	0.0 (34)	0.0 (1)	0.0 (52)
Roanoke Sound	3.0		0.0 (11)	0.0 (46)	0.0 (10)	0.0 (110)	0.0 (15)	0.0 (192)
Pamlico Sound	4.4		0.0 (92)	4.0 (1337)	4.2 (1004)	1.6 (1199)	2.6 (153)	3.1 (3785)
Pamlico River	5.3		0.0 (5)		0.0 (16)	0.0 (53)	0.0 (25)	0.0 (99)
Neuse River	5.1		0.0 (4)	1.5 (67)	0.0 (71)	0.0 (72)	0.0 (9)	0.5 (223)
Core Sound	3.9		11.4 (35)	6.7 (75)	8.3 (96)	0.0 (11)	11.9 (42)	8.5 (259)
North River	4.1	0.0 (7)	0.0 (31)	0.0 (14)	0.0 (10)	16.7 (12)	16.7 (6)	3.8 (80)
Newport River	4.5		2.7 (75)	3.4 (89)	2.7 (183)	0.0 (200)	0.0 (128)	1.5 (675)
Bogue Sound	4.3		1.8 (112)	2.1 (438)	0.0 (354)	1.0 (575)	0.3 (634)	0.9 (2113)
White Oak River	5.0		0.0 (26)	0.0 (26)	4.8 (42)	1.5 (68)	0.0 (46)	1.4 (208)
New River	3.8		1.6 (63)	0.8 (240)	0.0 (145)	0.0 (112)	0.0 (74)	0.5 (634)
Topsail Sound	3.3		12.5 (16)	0.0 (67)	0.0 (62)	0.0 (14)	3.1 (33)	1.6 (192)
Masonboro Sound	3.6	0.0 (12)	0.0 (3)	0.0 (42)	0.0 (59)	0.0 (164)	0.0 (27)	0.0 (307)
Cape Fear River	4.0	0.0 (4)	0.0 (14)	2.0 (151)	9.8 (112)	0.7 (135)	0.0 (50)	3.2 (466)
Lockwoods Folly & Shallotte Rivers	3.8			0.0 (16)	0.0 (9)	0.0 (3)	0.0 (5)	0.0 (33)
Intracoastal Waterway	3.9	0.0 (9)	0.0 (57)	1.3 (307)	0.0 (347)	0.5 (758)	0.4 (246)	0.5 (1724)
Total	4.8	0.5 (379)	2.0 (3674)	5.7 (13179)	3.0 (13469)	2.2 (13494)	2.2 (6038)	3.3 (50233)

** Percentage of sightings and total number of interviews (in parentheses) are given bimonthly for each water body. Only live turtle sightings are reported after April 1990. Live sightings represented 88% of all turtles reported since May 1990.*

Table 2. Sea turtles sighted in the Atlantic Ocean by recreational fishermen interviewed in North Carolina during the Marine Recreational Fishery Statistics Survey, 1989–1992.*

County of Interview	*Area Fished*	*Mean Hours Fished per Trip*	*Sightings*						
			Jan–Feb	*Mar–Apr*	*May–Jun*	*Jul–Aug*	*Sep–Oct*	*Nov–Dec*	*All Months*
Dare	nearshore	4.3	0.7 (301)	0.6 (1675)	3.9 (2571)	2.5 (2771)	1.2 (2681)	0.8 (2124)	1.9 (12123)
	offshore	6.2		7.8 (346)	6.8 (1840)	4.8 (2272)	8.1 (1788)	18.2 (336)	7.1 (6582)
Hyde	nearshore	4.0	0.0 (1)	0.0 (108)	1.8 (110)	2.7 (149)	2.2 (183)	0.0 (44)	1.7 (595)
	offshore	6.1		0.0 (6)	0.0 (16)	0.0 (32)	37.0 (27)	66.7 (3)	14.3 (84)
Pamlico	nearshore	2.7				0.0 (3)			0.0 (3)
Carteret	nearshore	4.3	0.0 (7)	4.4 (321)	10.4 (1447)	1.7 (1364)	0.7 (1594)	1.2 (723)	3.8 (5456)
	offshore	7.2		4.1 (122)	7.0 (830)	2.9 (1063)	4.9 (824)	23.0 (100)	5.3 (2939)
Onslow	nearshore	4.3		1.1 (88)	14.3 (488)	3.4 (385)	3.4 (322)	0.0 (176)	6.5 (1459)
	offshore	6.1		0.0 (3)	6.7 (45)	0.0 (35)	0.0 (28)	0.0 (5)	2.6 (116)
Pender	nearshore	5.0		12.5 (48)	9.1 (482)	1.2 (245)	0.0 (407)	0.7 (154)	4.0 (1336)
	offshore	4.8			0.0 (32)	8.1 (37)	0.0 (3)	0.0 (8)	3.8 (80)
New Hanover	nearshore	4.2	0.0 (31)	0.0 (222)	1.5 (987)	3.5 (965)	1.0 (868)	0.2 (458)	1.7 (3531)
	offshore	6.1		0.0 (45)	6.3 (352)	4.1 (688)	0.4 (521)	0.0 (28)	3.2 (1634)
Brunswick	nearshore	4.3	0.0 (4)	0.0 (65)	4.5 (558)	0.2 (480)	0.0 (409)	0.0 (291)	1.4 (1807)
	offshore	6.1	0.0 (3)	1.3 (76)	11.1 (424)	4.2 (332)	0.3 (296)	3.6 (84)	5.4 (1215)
Total	nearshore	4.3	0.6 (344)	1.2 (2527)	6.1 (6643)	2.3 (6362)	1.1 (6464)	0.7 (3970)	2.6 (26310)
	offshore	6.4	0.0 (3)	5.5 (598)	7.2 (3539)	4.1 (4459)	5.7 (3487)	15.8 (564)	6.0 (12650)

** Percentage of sightings and total number of interviews (in parentheses) are given bimonthly for each county. Only live turtle sightings are reported after April 1990. Live sightings represented 88% of all turtles reported since May 1990. Nearshore waters are defined as the territorial sea (within 5.6 km of shore) and offshore is defined as the Exclusive Economic Zone (beyond 5.6 km from shore).*

in offshore waters (4.2–6.1%). A notable exception occurred during May–June (and included July–August in one year), when sightings in nearshore and offshore waters were similar from the North Carolina–Virginia state line southward to the vicinity of Cape Lookout (Table 2). Sightings in inshore waters peaked during late spring and summer (Table 1).

Sightings of live turtles occurred during 1.9% of inshore trips, compared with 3.7% of ocean trips (Table 1). Trips by ocean fishermen, however, especially those in offshore waters, lasted approximately 18% longer than trips by inshore fishermen (Tables 1 and 2); therefore, the probability of ocean encounters was higher. Assuming each positive response represented a single turtle sighting, on average, ocean fishermen sighted a turtle every 135 hours of fishing; inshore fishermen sighted a turtle every 227 hours. The sighting proportions in some inshore waters appeared higher than in the Atlantic Ocean. Sightings of turtles in Core Sound (1 turtle/46 hours), Cape Fear River (1 turtle/124 hours),

Table 3. Bimonthly summary of public sightings of sea turtles in North Carolina inshore and offshore waters, 1989–1992.

Water Body	*Sightings*						
	Jan–Feb	*Mar–Apr*	*May–Jun*	*Jul–Aug*	*Sep–Oct*	*Nov–Dec*	*Total*
Atlantic Ocean	76	180	781	259	295	162	1753
Roanoke Sound	0	0	0	1	0	0	1
Pamlico Sound	0	3	102	28	13	3	149
Pamlico River	0	1	0	3	0	0	4
Neuse River	0	0	0	2	0	0	2
Core Sound	0	58	193	81	44	4	380
North River	0	0	5	2	0	0	7
Newport River	0	0	1	5	0	0	6
Bogue Sound	0	1	33	16	4	0	54
White Oak River	0	1	0	1	1	0	3
Browns Inlet	0	0	0	1	0	0	1
New River	0	0	3	0	1	0	4
Topsail Inlet	0	1	1	0	0	0	2
Rich Inlet	0	0	1	0	0	0	1
Masonboro Sound	0	0	5	1	0	0	6
Cape Fear River	0	1	4	4	0	0	9
Lockwoods Folly River	0	0	3	0	0	0	3
Shallotte River	0	0	1	1	0	0	2
Intracoastal Waterway	0	0	0	1	0	0	1
Total	76	246	1133	406	358	169	2388

Table 4. Reported public sightings of leatherback sea turtles (*Dermochelys coriacea*) in North Carolina, 1989–1992.

Month	Inshore	Atlantic Ocean	Total
Jan	0	2	2
Feb	0	0	0
Mar	0	0	0
Apr	0	9	9
May	28	223	251
Jun	24	69	93
Jul	1	15	16
Aug	2	9	11
Sep	1	7	8
Oct	0	7	7
Nov	0	8	8
Dec	3	0	3
Total	59	349	408

and Pamlico Sound (1 turtle/141 hours) were relatively high in all four years.

The public sighting postcard program yielded 536, 484, 589, and 779 reports of live turtles in 1989–1992, respectively. In addition to reports of free-swimming animals, public sighting reports included incidental captures by shrimp trawls, fish trawls, pound nets, gill nets, channel nets, and hook-and-lines. The majority of reports were from the ocean (Table 3). Sightings on the ocean were reported throughout the year, and sightings in inshore waters were reported all months except January–February (one sighting occurred in March and three sightings occurred in December, all from Core Sound). Sightings generally peaked during May–June in the ocean and inshore waters. Core Sound (60%), Pamlico Sound (23%), and Bogue Sound (9%) accounted for the majority of inshore sightings. Although most species identifications were unconfirmed, loggerhead, green, Kemp's ridley, and leatherback turtles were documented (by photograph, video, etc.) in inshore and ocean waters. The clearest seasonal pattern was for leatherbacks, the one species we assumed the public could reliably identify. Sightings before May were infrequent (Table 4). In early May, leatherbacks appeared to enter nearshore waters, coincident with the appearance of jellyfish. Leatherback turtles moved northward along the beach and were encountered infrequently in inshore waters, particularly Core Sound and Cape Lookout Bight. Sightings diminished after approximately four weeks and greatly declined by late June.

Biological Sampling

Commercial fishermen reported the incidental capture of 887 sea turtles in Pamlico and Core Sounds, 1988–1992 (Table 5); no mortalities were reported. Captures in pound nets accounted for 92% of the reports. Other captures were reported from shrimp trawls, long haul seines, and gill nets. Captures generally ceased by mid-December. Species composition was similar across years: loggerhead (79–93%), green (4–16%), and Kemp's ridley (1–8%). Leatherback and hawksbill turtles (*Eretmochelys imbricata*) never were reported captured by the cooperating fishermen. (A hawksbill turtle and a leatherback turtle were caught and released in Pamlico Sound during the study period. These incidental captures were reported to the Sea Turtle Stranding and Salvage Network [Tom Henson, North Carolina STSSN Coordinator, personal communication]). The proportion of green and Kemp's ridley turtles was highest in the fall and lowest in the summer.

Most loggerhead turtles were immature (see Crouse et al. 1987) (Fig. 2). Fishermen reported that some loggerheads were too large to handle; consequently, size distribution data are biased toward smaller individuals. Sizes ranged from 42 to 105 cm over-the-curve length (OCCL) ($\bar{X}$ = 66 cm OCCL, n = 70). Kemp's ridleys also were immature (Ogren 1989) and ranged from 32 to 55 cm OCCL ($\bar{X}$ = 43 cm OCCL, n = 14) (Fig. 2). One very small ridley was not measured (estimated size was 20–25 cm OCCL). Green turtles ranged from 24 to 70 cm OCCL ($\bar{X}$ = 33 cm OCCL, n = 21) (Fig. 2). Two very large green turtles (one estimated in excess of 50

Table 5. Incidental capture of sea turtles in Pamlico and Core Sounds, North Carolina, by species, 1988–1992, as reported by commercial fishermen.

Year	Sound	Number of Fishermen Reporting	Species				Total
			Caretta caretta	Chelonia mydas	Lepidochelys kempii	Unknown	
1988	Pamlico	4	77	13	10	11	111
	Core	2	58	8	1	0	67
1989	Pamlico	9	62	5	4	0	71
	Core	2	10	7	3	0	20
1990	Pamlico	6	88	6	1	0	95
	Core	2	36	1	0	3	40
1991	Pamlico	5	78	5	3	0	86
	Core	2	80	1	2	0	83
1992	Pamlico	6	79	15	6	1	101
	Core	2	179	34	0	0	213

kg and the other about 90 cm) escaped before being measured.

One hundred and seven turtles (68 loggerheads, 23 greens, and 16 Kemp's ridleys) were tagged and released during the project. During the first year, we found that tags placed on the trailing edge of front flippers could cause entanglement of immature turtles in nets. In Spring 1989, therefore, we began placing tags in the rear flippers, and no additional reports of entangled turtles have been received.

To date 16 turtles tagged by this project, and five turtles tagged elsewhere have been recaptured in Pamlico and Core Sounds: 14 loggerhead, four green, and three Kemp's ridley turtles. Most were recaptured shortly after release at or near the release site, but one returned to its release site during the following year. Two were recaptured more than once, including a loggerhead that was recaptured nine times during a two-month period. Turtles tagged and recaptured during the summer were more likely to be recaptured at the release site. Generally, turtles recaptured in the fall had exhibited southerly movements through the sounds. Turtles tagged and released to the north and to the south of the study area also were recaptured in the sounds: two from Long Island Sound, New York; one from Back Bay, Virginia; one from Port Canaveral, Florida; and one from Naples, Florida. We have no reports of turtles tagged in North Carolina sounds being recaptured outside the sounds.

Discussion

Survey methods using commercial fishermen, recreational anglers, and the general public each have their strengths and weaknesses. The Marine Recreational Fishery Statistics Survey provided estimates of the relative abundance of sea turtles for each water body, but the number of interviews was not sufficient to provide these estimates by season for the inshore waters bodies. The data were sufficient, however, to describe seasonal patterns of distribution across waters. The postcard sighting program provided the most seasonal information, but these data could not be used as a measure of relative abundance. Neither sighting program provided reliable data on species or size. Data on species, size composition, and seasonality of turtles in Core and Pamlico Sounds came from commercial fishermen, but these data could not be used to evaluate relative abundance or seasonality across all waters. Aerial surveys probably are the best method to determine relative abundance and seasonality of sea turtles over extensive and remote areas, but they cannot provide information on species and size composition. In addition, density estimates derived from aerial surveys of rare animals generally are accompanied by large confidence intervals (Eberhardt et al. 1979; Bayliss 1986; Epperly et al. in press). The described approaches to data collection are complementary. We conclude that descriptive studies of infrequently encountered animals may benefit from the simultaneous use of several methods.

The seasonal occurrence of turtles in inshore waters and the year-round occurrence of turtles in the Atlantic Ocean were confirmed by all sampling methods (Fig. 3). Virtually all sightings during January–March occurred in offshore waters (Tables 1, 2, and 3). Sightings were nearly equally divided between nearshore and offshore waters during May–June (Table 2). Turtles were observed in inshore waters April–December (Tables 1 and

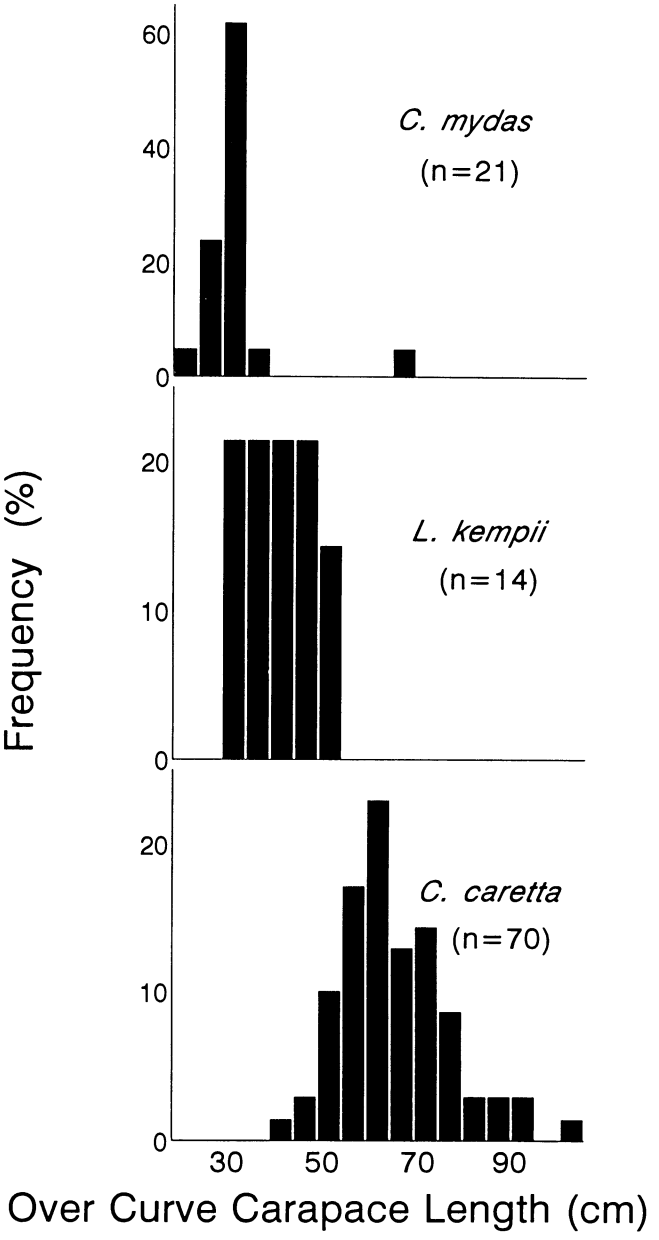

Figure 2. Over-the-curve standard carapace lengths of sea turtles taken as incidental captures in Pamlico and Core Sounds, North Carolina.

3). Aerial surveys of Pamlico and Core Sound confirmed the April–December inshore distribution (Epperly et al. in press). These observations suggested a seasonal pattern of offshore-onshore movement in the ocean and of immigration-emigration in inshore waters. Turtles appeared to move into nearshore and inshore waters as waters warmed in the spring and emigrated, presumably to offshore waters, as waters cooled in the late fall and early winter.

An alternative explanation for the lack of sightings during winter in inshore waters is that turtles in inshore and nearshore waters brumate, burying themselves in the bottom. Brumating turtles would not be visible to the public or from the air. We do not believe turtles generally brumate during winter in inshore waters of North Carolina because inshore waters are too cold. Weekly mean water temperatures generally drop below 8° C (Hettler & Chester 1982). This temperature is below that reported for brumating turtles (Felger et al. 1976; Carr et al. 1980) and also below the reported thermal tolerance of sea turtles (Schwartz 1978; Lutz & Dunbar-Cooper 1984; Lutz et al. 1989; Witherington & Ehrhart 1989; Moon 1992; Morreale et al. 1992). Despite an active bottom-trawl fishery during winter in Pamlico Sound, there has been only one confirmed report of a brumating turtle (Tom Henson, North Carolina STSSN Coordinator, personal communication).

Pound-net fishermen in the Pamlico-Core Sound area described the following seasonal pattern: multiple species early in the year, but predominately loggerhead sea turtles; loggerhead turtles almost exclusively through the summer and early fall; and multiple species again in the fall and early winter, when a high proportion of small green and Kemp's ridley sea turtles occurred. These compositional changes indicate that, during the summer and early fall, either sea turtle species segregated by habitat (with green and Kemp's ridley turtles selecting habitats outside the area where pound nets were set) or loggerheads remained more active than other species in the pound netting area and were more vulnerable to fixed gear. Thus, summer species composition data may be biased. All species should be equally vulnerable to fixed gear during immigration and emigration. Fall data, collected when turtles were emigrating past the full complement of fixed gear set behind the barrier islands, presumably would best represent the species composition of the local assemblage. From October–December, pound-net catches comprised

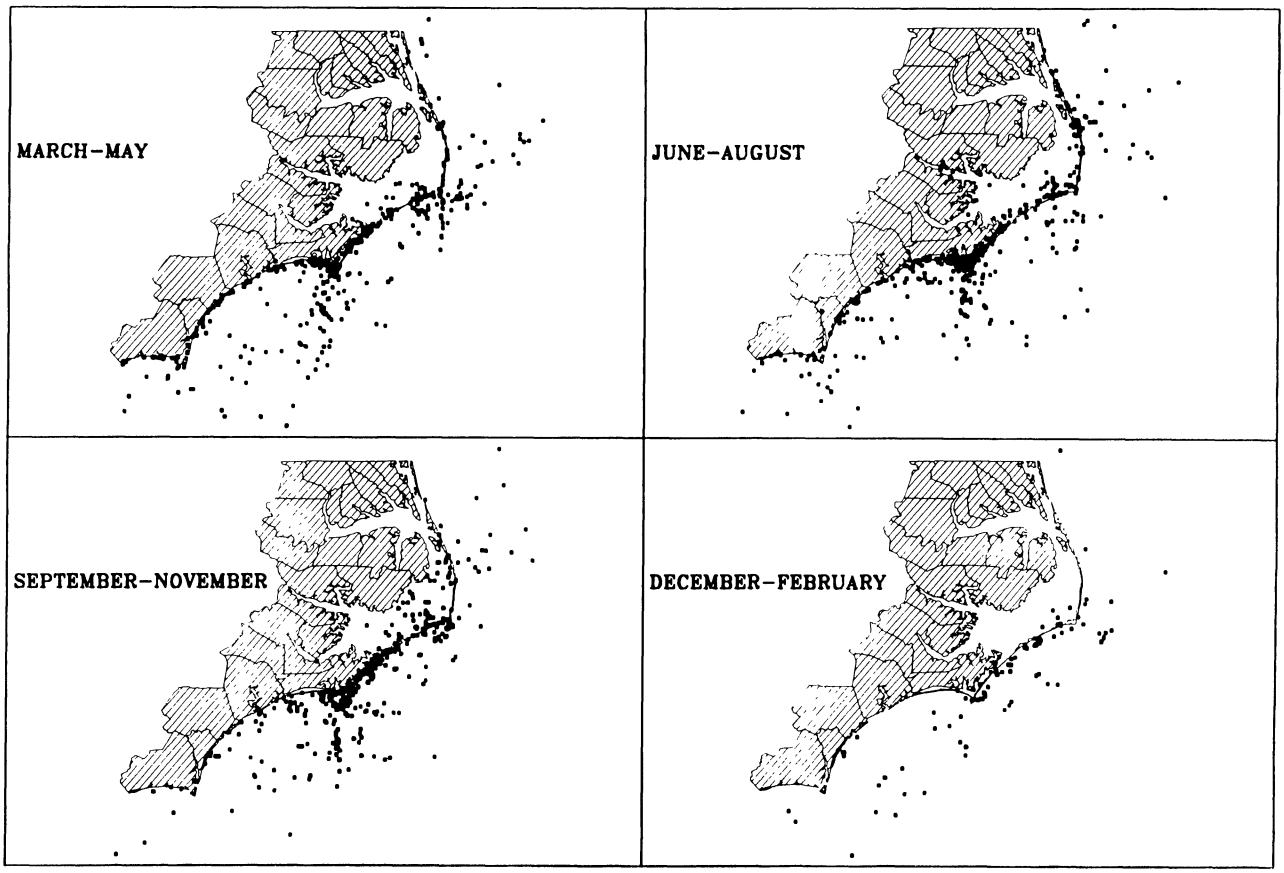

Figure 3. Seasonal occurrence of sea turtles in North Carolina waters. Sources of information are public sighting data, Marine Recreational Fishery Statistics Survey data, incidental capture data (this study), and aerial survey data (Epperly et al. in press).

80% loggerhead, 15% green, and 5% Kemp's ridley turtles.

Sea turtles in inshore waters have been studied extensively at four sites along the Atlantic Coast: Indian River, Florida; Pamlico and Core Sounds; Chesapeake Bay; and northern Long Island Sound and surrounding inshore waters. Except for Indian River, where entanglement nets were used, data were collected mostly from incidental captures in pound nets.

Three species are found regularly in the four areas: loggerhead, green, and Kemp's ridley. Loggerhead sea turtles are the most abundant (Table 6). The proportion of loggerhead turtles is similar from Chesapeake Bay southward but is lower in Long Island Sound. The smallest turtles are found in Long Island Sound. Loggerhead turtles to the south are larger and do not differ substantially in size from Chesapeake Bay to Indian River. Green turtles are similar in proportion in inshore waters from Long Island Sound to Indian River, except that they are nearly absent in Chesapeake Bay (Table 6). The size distributions of green turtles in Long Island Sound and Pamlico and Core Sounds are nearly identical. True (1884) noted that green turtles increase in size south of North Carolina. In fact, green turtles in the Indian River averaged 50% larger than those in North Carolina, but the differences were attributable to the increased abundance of larger turtles in Indian River, not to the absence of small turtles (Table 6). The proportion of Kemp's ridleys increases from south to north, and sizes increase from north to south (Table 6). This size gradient was recognized earlier, and both a decrease in the mean and in the range of sizes to the north has been noted (Carr 1980; Henwood & Ogren 1987; Ogren 1989; Morreale et al. 1992). Data from North Carolina fit the gradient and corroborate the previously described patterns. The smallest sizes in Long Island Sound (<30 cm) are virtually absent in the inshore waters to the south. With few exceptions, Kemp's ridley turtles along the Atlantic coast are immature (Ogren 1989).

Shoop and Kenney (1992) suggested that there is a northward movement of animals from south of Cape Hatteras in the spring and a southward movement of animals out of the Middle Atlantic Bight in the autumn. The time turtles spend in inshore waters decreases northward, a pattern consistent with this hypothesis. In Florida, turtles inhabit inshore waters throughout the year (Medonça & Ehrhart 1982). In North Carolina, turtles are found in inshore waters April through December. Turtles generally occur May through November in the Chesapeake Bay (Lutcavage & Musick 1985; Keinath

Table 6. Species composition and size (cm over-the-curve carapace length) of three species of sea turtles in the inshore waters of the Atlantic Coast of the U.S.

	Caretta caretta			*Chelonia mydas*			*Lepidochelys kempii*			
	Composition	*Size*		*Composition*	*Size*		*Composition*	*Size*		
Area	*(%)*	*Mean*	*Range*	*(%)*	*Mean*	*Range*	*(%)*	*Mean*	*Range*	*References*
Indian River	82	71	49–100	18	52	26–82	0[a]	61	57–64	Medonça & Ehrhart (1982) Ehrhart (1983) Witherington & Ehrhart (1989)
Pamlico and Core Sounds	80	66	42–105	15	33	24–70	5	43	32–55	this study
Chesapeake Bay	84	74	27–122	0.5	NA	NA	15	41	25–64[b]	Keinath et al. (1987) Lutcavage & Musick (1985)
Long Island Sound	58	54[c,d]	40–64[c]	14	35[c,e]	26–72[c]	24	31[c,f]	24–40[c,f]	Burke et al. (1992) Morreale et al. (1992) Burke et al. (1993) Stephen J. Morreale (personal communication)

[a] *Kemp's ridleys have been taken only in cold-stunning episodes in Indian River. Data for the three turtles are reported in Ehrhart (1983).*
[b] *Lutcavage and Musick (1985) depicted the size frequency data in 5-cm intervals. The values noted represent the beginning of the smallest interval and the ending of the largest interval.*
[c] *Straight-line carapace lengths were reported. For purposes of comparison, lengths have been converted to over-the-curve-carapace length estimates using the equations of Teas (1993).*
[d] *The mean size of loggerhead turtles obtained from cold-stunning in Long Island Sound (Morreale et al. 1992) was identical to that reported for loggerheads caught in the summer and used for diet studies (Burke et al. 1993).*
[e] *The mean size of 33-cm straight-line carapace length for green turtles was obtained from cold-stunned animals. Morreale et al. (1992) had insufficient numbers to test if the sizes of cold-stunned animals differed from the sizes of those caught in the summer and fall. However, Witherington and Ehrhart (1989) did not find significant differences in cold-stunned and net-caught green turtles in Indian River, Florida. In addition, Burke et al. (1992) reported that 90% of the green turtles captured in Long Island Sound were between 25 and 40 cm SLCL.*
[f] *Cold-stunned Kemp's ridley turtles were not significantly different in size from animals taken during summer and fall research activities (Morreale et al. 1992).*

et al. 1987) and June through October in the Long Island Sound area (Burke et al. 1992; Standora et al. 1992; Morreale & Standora 1995). The abundance of immature loggerhead and Kemp's ridleys in the ocean in the Cape Canaveral area is greatest during the winter, presumably when turtles are concentrated in the south (Henwood 1987; Henwood & Ogren 1987); size ranges are large, and all sizes documented to the north are represented. Turtles tagged in the northeast are recovered mostly in the southeast (Morreale & Standora 1995), and some turtles tagged in the southeast demonstrate northward movement (Henwood 1987; Henwood & Ogren 1987). Tag recaptures from the present study indicate that turtles enter North Carolina inshore waters from both the south (in spring/summer) and the north (fall), and at least one returned to the same area the following year (this study). Similar patterns of recapture have been reported for turtles in Chesapeake Bay (Lutcavage & Musick 1985; Keinath 1993).

Distribution patterns along the Atlantic Coast underscore the importance of temperate and subtropical inshore waters as developmental habitats for immature Kemp's ridley, green, and loggerhead sea turtles. Post-pelagic juvenile green and loggerhead turtles appear to recruit to estuaries along the Atlantic coast, except that green turtles are rarely observed in Chesapeake Bay (Brady 1925; Keinath et al. 1987). Post-pelagic juvenile Kemp's ridley turtles appear to recruit disproportionately to inshore waters of the northern latitudes. As waters cool in the fall, turtles emigrate from inshore waters of temperate latitudes, migrating southward at least as far as Cape Hatteras; as waters warm in the spring, immature turtles migrate inshore and northward, repopulating the inshore waters. As Kemp's ridley and green turtles age, they become more restricted to southern latitudes. Large loggerhead turtles are not restricted to southern waters, except for nesting, which occurs regularly as far north as North Carolina (Crouse 1984).

Evidence of the importance of inshore areas to sea turtles, along with evidence that shrimp trawlers working in inshore waters catch sea turtles (Renaud et al. 1991; Edward F. Klima, unpublished data, personal communication, June 9, 1992; this study), provided sufficient justification for the National Marine Fisheries Service to expand requirements for turtle excluder devices in the shrimp fishery to all areas at all times, including inshore waters; full implementation of these requirements was achieved by December 1994 (Federal Register 1992*a*, 1992*c*). Seasonal TED regulations, which allowed limits on tow lines to be substituted for TEDs in inshore waters, were fully implemented in 1990 and are estimated to have reduced sea turtle mortality associated with shrimp trawls by 67% (Henwood et al. 1992). Expanded TED regulations are expected to reduce mortality from shrimp trawling by 97% (Henwood et al. 1992; Federal Register, 1987, 1990, 1992*b*, 1992*c*). This reduction in mortality should allow turtles to realize a ten-fold increase in population size in half the time it would take with seasonal TED regulations alone (Crowder et al. 1994).

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