Marine turtle populations on the east-central coast of Florida: results of tagging studies at Cape Canaveral, Florida, 1986–1991*

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Abstract.—Marine turtle tagging records were collected off east-central Florida by a shrimp trawler from May 1986 to December 1991. The data were analyzed to determine species composition, size distribution, seasonal occurrence, movements, morphometrics, and growth of 928 incidentally captured turtles. Loggerhead turtles, *Caretta caretta*, were the most frequently captured species (83% of total catch), while Kemp's ridley, *Lepidochelys kempi*, and green turtles, *Chelonia mydas*, were caught less frequently (12% and 4%, respectively). The loggerhead turtle population consisted of a seasonably variable aggregation of subadult and adult turtles. The Kemp's ridley and green turtle populations were composed of subadult turtles and were captured primarily during winter months. Kemp's ridley and loggerhead turtles appeared to exhibit a seasonal north-south migrational pattern along the Atlantic coast. Regression equations were developed for the morphometric relationships of each species. Average yearly growth rates and estimates for the von Bertalanffy growth interval equation were calculated for loggerhead and Kemp's ridley turtles. These results indicate that the coastal waters of the Cape Canaveral area provide an important developmental habitat for the three species of marine turtle.

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The marine turtle life history is a dynamic progression of stages which includes oceanic dispersal of the offspring and utilization of a series of distinct developmental habitats (Carr, 1980; Hendrickson, 1980). The early in-water stages of marine turtle development have not been as extensively studied as the reproductive stage of females. Information concerning the early life histories of threatened and endangered marine turtles is critical in formulating conservation and recovery strategies as mandated by the Endangered Species Act of 1973 and subsequent amendments.

Inaccessibility of immature turtles in the open ocean is the major factor contributing to the lack of information on the early stages of development. Other than possible current-mediated dispersal scenarios (Carr, 1986; Collard and Ogren, 1990), little is known about the pelagic stage of marine turtle development. However, information concerning the populations of immature turtles foraging in the coastal waters of eastern Florida has been accumulating as a result of data collected through commercial fisheries (fishery-dependent) and fishery-independent activities.

Fishery-independent capture and tagging efforts have characterized the populations of loggerhead turtles, *Caretta caretta*, and green turtles, *Chelonia mydas*, foraging in the northern part of the Indian River lagoon system (Ehrhart and Yoder, 1978; Mendonça, 1981, 1983; Mendonça and Ehrhart, 1982; Ehrhart, 1983). All green turtles collected in the lagoonal habitat were immature, as were almost all of the loggerhead turtles. Aggregations of marine turtles in the Port Canaveral ship channel were first reported in 1978, when two trawlers caught unprecedented numbers of loggerhead turtles while searching for a concentration of shrimp (Carr et al., 1980). This prompted the National Marine Fisheries Service (NMFS) to conduct trawl surveys of the ship channel from 1978 to 1984 (Butler et al., 1987; Henwood, 1987a; Henwood and Ogren, 1987). The surveys provided information on the seasonal occurrence and movement patterns of subadult and adult loggerhead turtles (Henwood, 1987a), as well as subadult Kemp's ridley, *Lepidochelys*

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kempi, and green turtles (Henwood and Ogren, 1987) captured in the vicinity of Cape Canaveral. In addition, the results of research conducted in response to incidental mortality of marine turtles due to dredging in the Port Canaveral ship channel were presented at the Cape Canaveral Sea Turtle Workshop (Witzell, 1987).

In 1986, the NMFS Panama City Laboratory initiated long-term studies of marine turtles found along the northwest (Cedar Keys) and east-central (Cape Canaveral) coasts of Florida (Schmid and Ogren, 1990). The Kemp's ridley turtle was the target species in both study areas. This paper presents the results of NMFS marine turtle studies conducted in nearshore waters of east-central Florida from 1986 to 1991. Information concerning marine turtle species composition, relative abundance, size frequency, seasonal occurrence, movements, morphometrics, and growth is provided.

Materials and methods

Data collection

A commercial shrimp-fishing vessel was contracted by NMFS, from May 1986 to December 1991, to measure, tag, and release marine turtles incidentally captured during trawling. Fishing effort and location were a function of the seasonal abundance of brown shrimp, *Penaeus aztecus*, and white shrimp, *Penaeus setiferus*. Trawling was conducted between St. Mary's Entrance, 30°43'N, and Sebastian Inlet, 27°52'N (Fig. 1), and was concentrated in the Cape Canaveral area, 28°30'N to 28°15'N, as defined by Henwood (1987a). Fishing effort did not extend beyond 24 km offshore and 25.6 m in depth. The majority of effort occurred less than 8 km offshore and 13.4 m in depth. Trawling gear consisted of four 12.2-m or 12.8-m nets (two on each side) for targeting brown shrimp, or two 24.4-m nets (one on each side) for targeting white shrimp.

Captured turtles were double tagged on the trailing edge of the fore flippers with #681 Inconel cattle ear tags. Tagging information for each turtle included: tag codes, species, date, location of capture, latitude and longitude, depth, gear type, standard straight-line carapace length (SSCL; nuchal notch to posterior end of postcentral), and straight-line carapace width. Carapace length and width were measured to the nearest 0.1 inch with forester's calipers and were converted to metric units for analysis. Kemp's ridley and green turtles were weighed with a 15-kg capacity spring scale. Notes on the condition of the turtle were recorded when the animal was injured or deformed (e.g. missing flipper, carapace wounds, etc.).

NMFS issued Sea Turtle Conservation Regulations on 29 June 1987 (Federal Register, 1987) that required vessels 25 feet (7.6 m) long or longer to use Turtle Excluder Devices (TED's) in the Cape Canaveral area beginning 1 October 1987. Subsequently, a NMFS permit was issued authorizing the contract vessel to conduct a TED testing program during fishing operations. The testing procedure consisted of towing a net(s) equipped with a Morrison soft TED on one side of the boat and a net(s) without a TED on the other side. Pounds of shrimp, marine turtle captures, and total catch (when possible) were recorded for the trawl types. Effort data were available for 1989–91, including trawl size and type, number of tows and total tow time, and number of days fished.

Data analysis

The terms "juvenile" and "subadult" used to describe the early stages of the marine turtle life history are

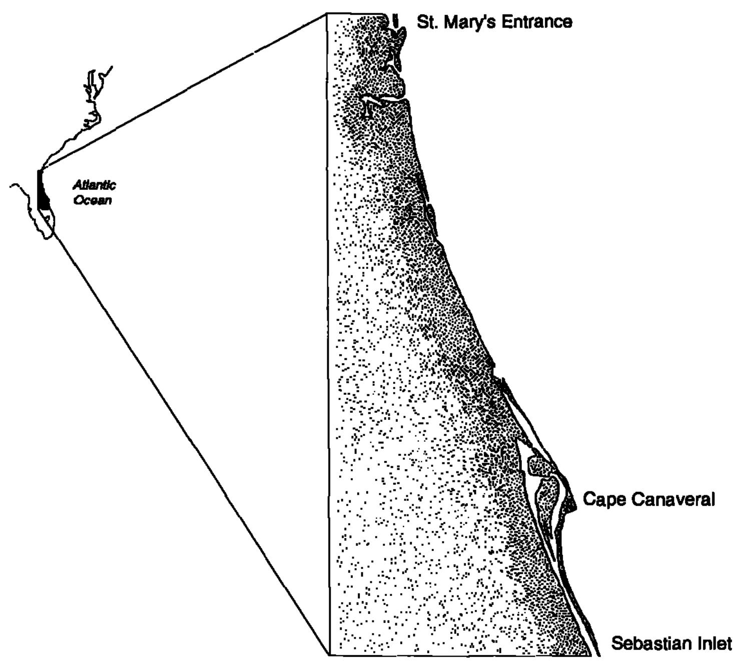

Figure 1

Sampling areas for marine turtles (*Caretta caretta*, *Lepidochelys kempi*, and *Chelonia mydas*) off the Atlantic coast of Florida from 1986 to 1991.

not well defined. In this study, the term "juvenile" has been reserved for immature turtles in the pelagic stage of development. A turtle is considered "subadult" when it has recruited to its respective coastal-benthic habitat and "adult" when sexually mature. Loggerhead turtles greater than 80-cm carapace length were considered adult, based on the length frequencies of Cape Canaveral nesting females (Carr, 1986, and references therein) and earlier investigations of Henwood (1987a). Kemp's ridley turtles greater than 60-cm carapace length were considered adult (Pritchard and Márquez, 1973).

Monthly trawling effort was calculated and standardized according to Henwood and Stuntz (1985) by using the formula

$$E = \left(\frac{Nets \cdot Length}{30.5}\right)\left(\frac{Min}{60}\right),$$

where E is the trawling effort in hours towed by a single 30.5-m headrope length net, *Nets* is the number of nets towed, *Length* is the headrope length (m) of a net, and *Min* is the number of minutes fished.

Capture records were analyzed to evaluate species composition within the study area, length-frequency distribution of each species, and patterns of seasonal distribution and movements. Linear regression analyses were performed for carapace width on length for loggerhead turtles. The morphometric data for loggerhead turtles were subdivided into a subadult group (<80 cm SSCL) and an adult group (≥80 cm SSCL) because the carapace dimensions of this species change as the animals mature (Henwood and Moulding, 1987). Carapace width was regressed on length, and weight regressed on length for Kemp's ridley and green turtles. Turtles with carapace wounds or deformities were not included in the analyses. Regression residuals for length-weight relationships were analyzed graphically to assess the appropriateness of the straight-line model (Sokal and Rohlf, 1981; Kleinbaum et al., 1988).

Curved carapace lengths (CCL) of stranded turtles were converted to straight-line carapace lengths (SCL) by using the following regression equations of Teas (1993):

$$SCL = -1.442 + (0.948 \times CCL)$$
for loggerhead turtles;

$$SCL = 0.013 + (0.945 \times CCL)$$
for Kemp's ridley turtles.

Total straight-line carapace lengths (*TSCL*) of loggerhead turtles were converted to standard straight-line carapace lengths (*SSCL*) with the regression equation of Henwood and Moulding (1987):

$$SSCL = (0.9964 \times TSCL) - 0.775.$$

Yearly growth rates were calculated from the formula

$$G = \left(\frac{\Delta Length}{Days}\right)365$$

where G is the growth rate in cm/yr, $\Delta Length$ is the difference between the recapture length and the initial length, and *Days* is the number of days out. The von Bertalanffy growth interval equation was fitted to the recapture data with a nonlinear least-squares regression procedure (SAS, 1988). The von Bertalanffy growth interval equation (Fabens, 1965) for recapture is as follows:

$$CL_2 = a - (a - CL_1)e^{-kt},$$

where CL_2 is the carapace length at recapture, a is the asymptotic length, CL_1 is the length at first capture, K is the intrinsic growth rate, and t is the time in years between captures.

Results

Trawling effort

Monthly trawling effort varied from year to year (1989–91); however, monthly totals for all three years indicate that the majority of effort occurred from May to December (Table 1). This corresponds to the summer-fall fisheries for brown and white shrimp, the target species during this study. Monthly turtle capture rates were also variable, probably as a result of the combined seasonal fluctuations in trawling effort and turtle abundance. A structured sampling scheme with equal monthly effort would be required to make accurate calculations of monthly changes in turtle abundance. Loggerhead turtle catch per unit of effort (CPUE) ranged from 0.02 turtles/net hour in October 1989 to 1.09 turtles/net hour in August of 1991. Maximum CPUE of 0.25 turtles/net hour was obtained for Kemp's ridley turtles in May 1990 and 0.05 turtles/net hour was obtained for green turtles in January 1989 (Table 1).

Species composition

A total of 774 (83%) loggerhead, 113 (12%) Kemp's ridley, and 41 (4%) green turtles were captured, tagged, and released during the course of the study. A leatherback turtle, *Dermochelys coriacea*, was also captured and tagged. Sixty tagged turtles (42 loggerhead, 15 Kemp's ridley, and 3 green) were recaptured by the contract vessel. Additionally, 31 recaptures and recoveries (26 loggerhead, 4 Kemp's ridley, and 1 green turtle) were reported by other investigators.

Loggerhead turtle, *Caretta caretta*—Seven hundred and seventy-four loggerhead turtle captures were recorded off the east coast of Florida. Loggerhead turtles captured in Florida ranged from 38.2 to 110.0 cm SSCL (Fig. 2). Eighty percent (n=616) of the loggerhead turtles captured were subadults and 20% (n=153) were adults. Loggerhead turtles were present year-round in the Cape Canaveral area (Table 2). Total monthly captures were highest during November, December, and January; however, yearly captures for these months varied substantially. Subadult loggerhead turtles were most abundant during all months, except June, and showed a decrease from April to July as adult abundance increases, probably in response to the nesting season (Fig. 3). Peaks in the relative composition of the adult size class during April and June correspond to the peak densities reported by Henwood (1987a) for males and females, respectively.

Sixty-eight tagged loggerhead turtles have been recaptured or recovered since the implementation of this study. Fifty-two (76%) of these turtles were initially tagged by the contract vessel. The remaining sixteen (24%) loggerhead turtle recaptures were tagged by other investigators in Florida and Georgia.[1,2,3,4,5,6,7] Methods of capture included shrimp trawl (69%), beach stranding (22%), pound net (3%), power plant intake canal (3%), nesting female (1%), and SCUBA sighting (1%). The amount of time between tagging and recapture ranged from 1 to 2,499 days. However, 70% (n=45) were recaptured within a year of initial capture.

Twenty-six loggerhead turtles (23 subadults and 3 adults) initially captured

Table 1

Monthly trawling effort (net hours) and turtle capture rates (turtles/net hour) for 1989–91. Cc=*Caretta caretta*, Lk=*Lepidochelys kempi*, and Cm=*Chelonia mydas*.

Year and month	Effort (net hours)	Total turtles/hr	Species		
			Cc/hr	Lk/hr	Cm/hr
1989					
Jan	77.0878	0.3113	0.2465	0.0130	0.0519
Feb	13.1918	0.2274	0.0758	0.1516	0.0000
Mar	25.9838	0.3079	0.2694	0.0385	0.0000
Apr	41.1742	0.2672	0.1700	0.0971	0.0000
May	103.9350	0.0770	0.0673	0.0096	0.0000
June	123.1230	0.1462	0.0568	0.0650	0.0244
July	70.7558	0.1555	0.1555	0.0000	0.0000
Aug	72.7545	0.1924	0.1787	0.0137	0.0000
Sept	19.9875	0.1001	0.1001	0.0000	0.0000
Oct	49.5690	0.0202	0.0202	0.0000	0.0000
Nov	139.1130	0.1006	0.0719	0.0216	0.0072
Dec	56.3648	0.1242	0.1064	0.0177	0.0000
1990					
Jan	27.1830	0.1104	0.1104	0.0000	0.0000
Feb	57.5640	0.2258	0.1737	0.0521	0.0000
Mar	18.3885	0.4894	0.4350	0.0544	0.0000
Apr	23.1855	0.4313	0.3450	0.0863	0.0000
May	15.9900	0.7505	0.5003	0.2502	0.0000
June	31.5802	0.1583	0.1583	0.0000	0.0000
July	147.1080	0.1971	0.1971	0.0000	0.0000
Aug	117.5265	0.0851	0.0851	0.0000	0.0000
Sept	—	—	—	—	—
Oct	—	—	—	—	—
Nov	148.3072	0.1483	0.1079	0.0067	0.0337
Dec	127.5202	0.2666	0.2196	0.0235	0.0235
1991					
Jan	28.7820	0.8686	0.7991	0.0695	0.0000
Feb	23.1855	0.2588	0.2588	0.0000	0.0000
Mar	35.9775	0.1946	0.1668	0.0278	0.0000
Apr	21.5865	0.2780	0.2780	0.0000	0.0000
May	92.7420	0.2588	0.2588	0.0000	0.0000
June	33.5790	0.4467	0.4467	0.0000	0.0000
July	35.7776	0.6988	0.6988	0.0000	0.0000
Aug	21.9862	1.0916	1.0916	0.0000	0.0000
Sept	—	—	—	—	—
Oct	43.3089	0.2309	0.2078	0.0231	0.0000
Nov	77.5515	0.0903	0.0903	0.0000	0.0000
Dec	106.7332	0.1031	0.1031	0.0000	0.0000
Total	2,028.60				

[1] Bolten, A. University of Florida, Archie Carr Center for Sea Turtle Research, Gainesville, FL, 32611. Personal commun., 1992.

[2] Foster, K. National Marine Fisheries Service, Miami Laboratory, 75 Virginia Beach Drive, Miami, FL, 33149. Personal commun., 1994.

[3] Guseman, J. University of Central Florida, Department of Biology, Orlando, FL, 32816. Personal commun., 1992.

[4] Henwood, T. National Marine Fisheries Service, Southeast Regional Office, 9450 Koger Boulevard, St. Petersburg, FL, 33702. Personal commun., 1991.

[5] Martin, E. Applied Biology, Inc., P.O. Box 974, Jensen Beach, FL, 34958. Personal commun., 1991.

[6] Stuntz, W. National Marine Fisheries Service, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS, 39567. Personal commun., 1991.

[7] Teas, W. National Marine Fisheries Service, Miami Laboratory, 75 Virginia Beach Drive, Miami, FL, 33149. Personal commun., 1991.

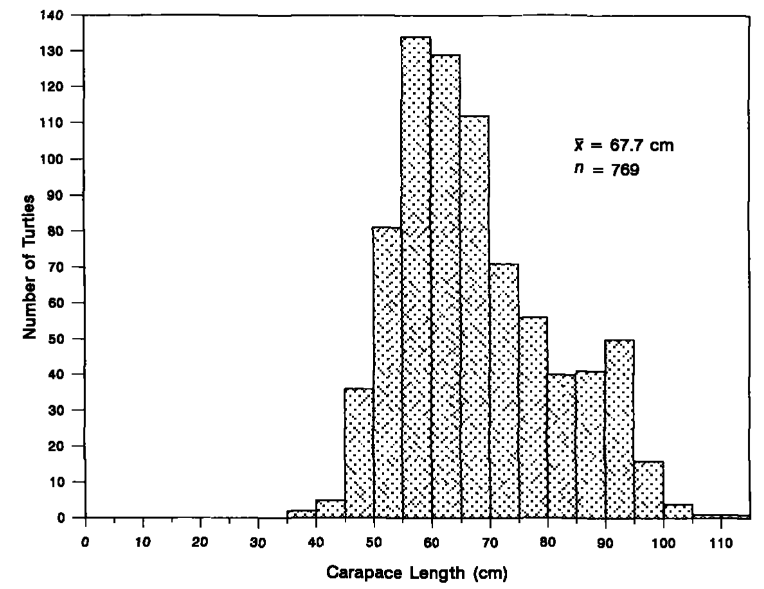

Figure 2

Length frequencies of loggerhead turtles, *Caretta caretta*, collected along the Atlantic coast of Florida from 1986 to 1991.

Table 2

Monthly and yearly trawl captures of loggerhead turtles, *Caretta caretta*, in the nearshore waters of Florida. Dashes indicate trawling effort outside of the study area.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1986					1	5/—	—	—	—/5	37	31	44	123
1987	90	47	31	12	5	11/—	—	—	—	—/3	2	0	201
1988	1	0	16	1	2	0	4	3	2	6	8	15	58
1989	19	1	7	7	7	7	11	13	2	1	10	6	91
1990	3	10	8	8	8	5	29	10	10	10	16	28	145
1991	23	6	6	6	24	15	25	24	—	9	7	11	156
Total	136	64	68	34	47	43/—	69/—	50/—	19/—	66/—	74	104	774

within the Cape Canaveral study area were subsequently recaptured within this area. Of this total, eleven turtles (9 subadults and 2 adults) were captured and recaptured in the Port Canaveral ship channel. Eight loggerhead turtles captured in the Cape Canaveral area during the winter were recaptured or recovered in Georgia, North Carolina, and Virginia during the summer and fall (Fig. 4). All these turtles were subadults ranging from 51 to 61 cm carapace length. Three tagged loggerhead turtles (two subadults and a nesting female) were reported south of Cape Canaveral by fishery-independent sources.

There was a stronger correlation between carapace width and carapace length for subadult loggerhead turtles (r=0.9612; n=508) than for adults (r=0.7724; n=151). Regression equations were computed for the relationship of carapace width (CW) to length ($SSCL$) for subadults:

$$CW = 9.0289 + 0.6848\ (SSCL);$$

and adults

$$CW = 22.9153 + 0.5052\ (SSCL).$$

Fifty-one yearly growth rates were calculated for forty-nine loggerhead turtles. Extrapolating annual growth rates from these data is difficult owing to the

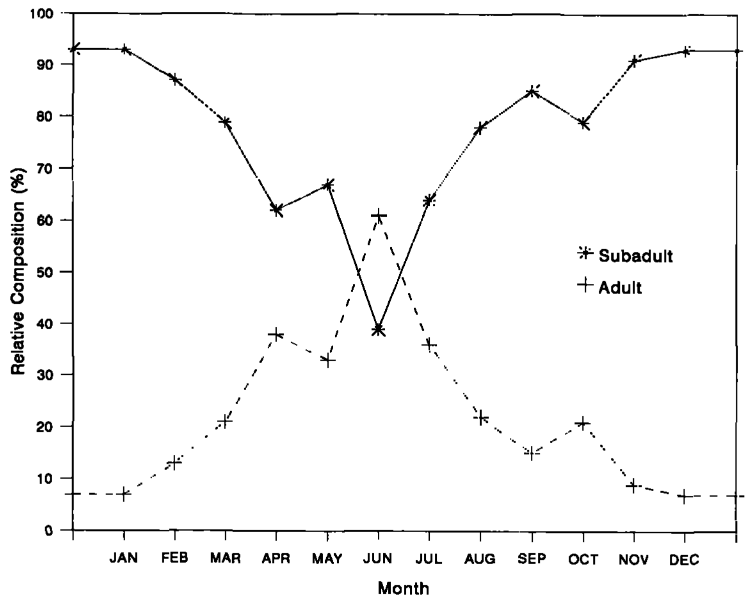

Figure 3

Relative composition of subadult and adult loggerhead turtles collected along the Atlantic coast of Florida from 1987 to 1991.

small sample sizes, measurement errors, and short-term recaptures. A number of treatments were applied to the growth data in an attempt to control for measurement error. However, no single approach was able to account for all the error. Consequently, growth rates were calculated for 1) all data combined, 2) those tag and recapture data recorded by the contracted personnel, and 3) those data with recapture intervals greater than 90 days. A mean growth rate of 5.56 ± 23.91 cm/yr (range: –11.49 to 167.17 cm/yr) was calculated for all loggerhead turtle recaptures. Analysis of the loggerhead turtles tagged and recaptured by the contract personnel indicated a mean growth rate of 1.00 ± 1.23 cm/yr (range: 0.00 to 4.01 cm/yr). Additionally, a mean growth rate of 2.98 ± 7.12 cm/yr (range: –5.96 to 38.44 cm/yr) was calculated for all loggerhead turtle recaptures greater than 90 days at large, 1.84 ± 1.76 cm/yr (range: –0.23 to 8.08 cm/yr) for all recaptures greater than 180 days at large, and 1.77 ± 1.88 cm/yr (range: –0.23 to 8.08 cm/yr) for all recaptures greater than 360 days at large.

The von Bertalanffy growth interval equation was fitted to each of these data treatments. Estimates of asymptotic length (a) for loggerhead turtles ranged from 96.08 cm to 112.52 cm and estimates of intrinsic growth rate (K) ranged from 0.0365 to 0.0588 (Table 3). The growth model for captures and recaptures by the contract vessel had the lowest residual mean square, a criterion commonly used to select the best fit growth model (Dunham, 1978). The estimated parameters for this data treatment (a=112.52 cm; K=0.0365) are similar to Henwood's (1987b) estimated parameters for nonlinear regression of the von Bertalanffy equation (a=110.002 cm; K=0.0313).

Kemp's ridley turtle, *Lepidochelys kempi*—One hundred and thirteen Kemp's ridley turtle captures were recorded on the Atlantic coast of Florida. Kemp's ridley turtles ranged in size from 21.5 to 60.3 cm SSCL (Fig. 5). Sixty-five percent (n=70) of these turtles were early to mid-subadults (20–40 cm). With the exception of a single adult turtle, the Kemp's ridley turtles caught on the east coast were classified as immature. Kemp's ridley turtles were captured year-round in the Cape Canaveral area (Table 4). Their presence in the Cape Canaveral area appeared to be seasonal; 61% (n=69) of the turtles were captured during the winter months of December to March. However, a relatively large number of Kemp's ridley turtles captured in January and February of 1987 and in March of 1988 contributed significantly to this trend. Captures of Kemp's ridley turtles during the following years did not exhibit a pronounced seasonal pattern.

Nineteen tagged Kemp's ridley turtles were recaptured or recovered. Eighty-nine percent (n=17) of the turtles were recaptured by shrimp trawls, and 11% (n=2) were recovered from beach strandings. With the exception of a single turtle captured in the area

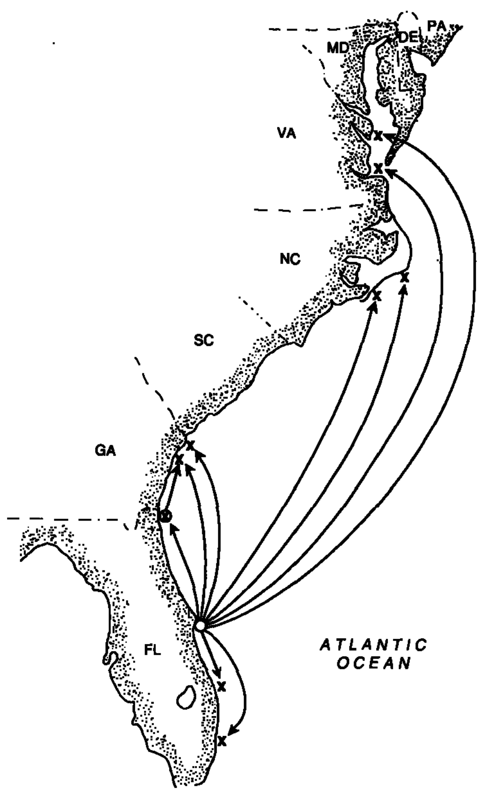

Figure 4

Long-distance recaptures and recoveries of tagged loggerhead turtles. Note: Arrows are not intended to indicate routes traveled by tagged turtles; they are a visual aid to differentiate tagging and recapture sites. O=tagging location; X=recapture location.

of initial tagging after 615 days at large, all Kemp's ridley turtles were recaptured within a year.

Twelve (63%) Kemp's ridley turtles were initially captured in the Cape Canaveral area and subsequently recaptured within this area. Of this total, four turtles were captured and recaptured in the Port Canaveral ship channel. Two Kemp's ridley turtles had multiple recaptures within the Cape Canaveral area, one tagged in November 1986 was caught once in December 1986 and again in May 1987. Another turtle tagged in May 1990 was recaptured twice that September.

Six Kemp's ridley turtles exhibited long-distance movements to and from the Cape Canaveral area (Fig. 6). Two of the recaptures were NMFS Galveston Laboratory headstart turtles released offshore of Padre Island, Texas, in May and captured on the Atlantic coast of Florida in February and March, 0.73 and 1.88 years after release.[8] Two Kemp's ridley turtles displayed seasonal movements northward. The turtles were originally tagged in the Cape Canaveral area in December and February and subsequently recovered in Georgia and South Carolina in July. Another Kemp's ridley turtle exhibited a southerly migration along the Atlantic coast, from Virginia Beach to Port Canaveral.[9]

There was a strong correlation between carapace width and carapace length (r=0.9953; n=105) for Kemp's ridley turtles. Regression of carapace width on length resulted in the equation

$$CW = -2.7157 + 1.0288\,(SSCL).$$

A straight-line equation was applied to the length-weight data; however, graphical analysis of the residuals indicated a curvilinear relationship between the two variables. Power regression was performed through the log-log transformation of weight and length measurements. A strong correlation (r=0.9756; n=88) was calculated for the transformed weight (WT) to length relationship, regression of these variables resulted in the equation

$$\log WT = -8.2837 + 2.8444\,(\log SSCL).$$

Twelve yearly growth rates were computed for ten Kemp's ridley turtles. A mean growth rate of 8.28 ± 9.81 cm/yr (range: 0.00 to 29.16 cm/yr) was calculated for all Kemp's ridley turtle recaptures. Analysis of the Kemp's ridley turtles tagged and recaptured by the contract personnel indicated a mean growth rate of 6.92 ± 9.36 cm/yr (range: 0.00 to 29.16 cm/yr). A mean growth rate of 8.79 ± 10.32 cm/yr (range: 0.00 to 29.16 cm/yr) was calculated for recaptures greater than 90 days at large and 5.94 ± 1.80 cm/yr (range: 4.26 to 7.84 cm/yr) for recaptures greater than 180 days at large.

The von Bertalanffy growth interval equation was fitted to each of these data treatments. Estimates of asymptotic length ranged from 60.66 cm to 77.85 cm and estimates of intrinsic growth rate ranged from 0.0577 to 0.6037 (Table 5). Asymptotic lengths were probably underestimated because of the lack of adult-sized Kemp's ridley turtles in the database.

Green turtle, *Chelonia mydas*—Forty-one green turtles, ranging in size from 24.0 to 55.4 cm SSCL (Fig. 7), were taken from Florida waters. Eighty-one percent (n=33) of the green turtles captured off the east coast of Florida were early subadults less than 40 cm SSCL. No adult green turtles were encountered.

[8] Caillouet, C., Jr. National Marine Fisheries Service, Galveston Laboratory, 4700 Avenue U, Galveston, TX, 77551. Personal commun., 1991.

[9] Keinath, J. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA, 23062. Personal commun., 1993.

The presence of subadult green turtles in the Cape Canaveral area appeared highly seasonal (Table 6); 73% (n=30) were captured from November to January. As with other turtle species, this pattern resulted from a high number of captures in 1987 and a high monthly variation during other years.

Four tagged green turtles were recaptured during this study. Three turtles were originally tagged by contract personnel in the Cape Canaveral area. The tag codes for the fourth green turtle matched a set of NMFS tags that had been distributed to Fort Lauderdale, Florida. Of the three green turtles tagged at Cape Canaveral, one was initially tagged in January 1987 and then recaptured in April, approximately 68 km to the north. Another green turtle that was initially tagged in the Cape Canaveral area in January 1990 was recaptured in this area the following October. A third green turtle was captured off Port Canaveral in September 1990 and found stranded approximately 41 km to the north the following month.

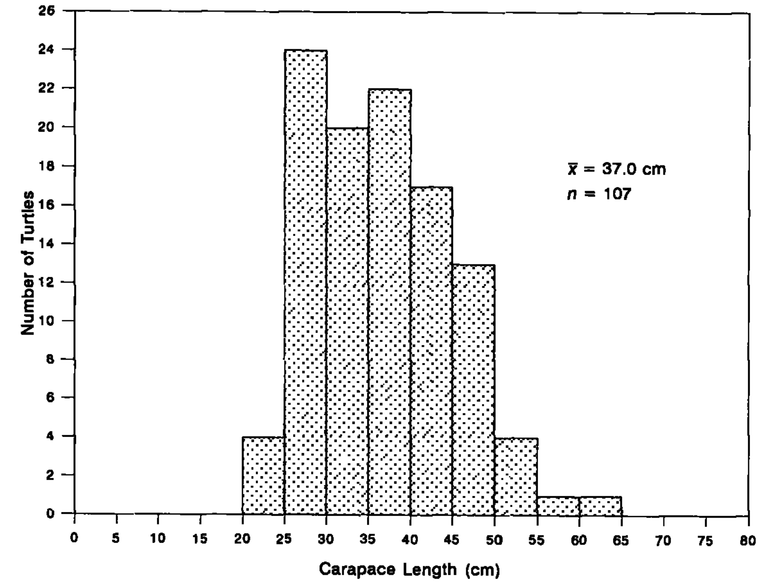

Figure 5

Length frequencies of Kemp's ridley turtles, *Lepidochelys kempi*, collected along the Atlantic coast of Florida from 1986 to 1991.

There was a strong correlation (r=0.9590; n=39) between carapace width and carapace length for green turtles. Regression of carapace width on carapace length resulted in the equation

$$CW = 4.1763 + 0.6847\ (SSCL).$$

Residual analysis of the length-weight relationship indicated the need for curvilinear terms in the regression model. A strong correlation (r=0.9587; n=37) was calculated for the log-transformed weight to length relationship, and regression of these variables resulted in the equation

$$\log WT = 8.8784 + 2.9815\ (\log SSCL).$$

There were no growth data available for green turtles owing to the relatively low number of recaptures and the lack of data for the recoveries.

Table 3

Estimated values of asymptotic length (a) and intrinsic growth rate (k) from nonlinear regression of von Bertalanffy growth interval equation for loggerhead turtles (one asymptotic standard error in parentheses).

Data treatment	n	a	k
All recaptures	51	96.08 cm	0.0586
		(7.07)	(0.0149)
	Residual mean square error = 9.1054		
Capture/recapture by contract vessel	17	112.52 cm	0.0365
		(24.74)	(0.0204)
	Residual mean square error = 0.4088		
All recaptures >90 days	33	96.09 cm	0.0588
		(8.72)	(0.0185)
	Residual mean square error = 13.8969		
All recaptures >180 days	24	96.40 cm	0.0569
		(7.97)	(0.0162)
	Residual mean square error = 10.8231		
All recaptures >365 days	19	96.10 cm	0.0573
		(8.82)	(0.0183)
	Residual mean square error = 13.5947		

Discussion

The data for this project were collected incidentally through the commercial shrimp fishery of east-central Florida. Bias in trawling effort oc-

Table 4

Monthly and yearly trawl captures of Kemp's ridley turtles, *Lepidochelys kempi*, in the nearshore waters of Florida. Dashes indicate trawling effort outside of the study area.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1986	1[1]				1	0/—	—	—	—/0	1	1	4	8
1987	13	10	4	1	0	1/—	—	—	—	—/1	1	2	33
1988	1	0	17[1]	0	0	0	2	1	1	1	2	2	27
1989	1	2	1	4	1	8	0	1	0	0	3	1	22
1990	0	3	1	2	4	0	0	0	4	1	1	3	19
1991	2	0	1	0	0	0	0	0	—	1	0	0	4
Total	17	16	24	7	6	9/—	2/—	2/—	5/—	5/—	8	12	113

[1] Recapture of a NMFS Galveston Laboratory Headstart Kemp's ridley turtle.

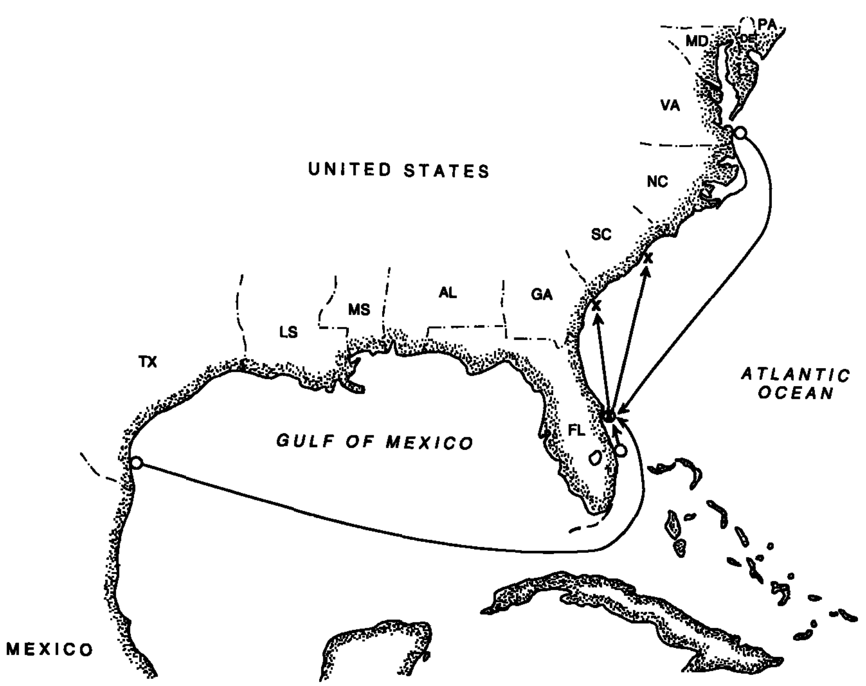

Figure 6

Long-distance recaptures and recoveries of tagged Kemp's ridley turtles Note: Arrows are not intended to indicate routes traveled by tagged turtles; they are a visual aid to differentiate tagging and recapture sites. O=tagging location; X=recapture location.

curred because amount of effort and location of trawling were a function of shrimp abundance. These factors certainly contributed to the annual, and possibly seasonal, variation in turtle captures observed in this study. Restrictions imposed on the shrimping industry during the course of the study also affected data collection. There was a marked reduction in the number of loggerhead captures following NMFS regulations issued in June 1987, requiring the use of TED's in the Cape Canaveral area (Federal Register, 1987). Despite the bias and inconsistencies of data collection, the use of trawl gear allowed access to marine turtle developmental stages not encountered in nesting beach surveys and inshore netting studies. Furthermore, the Cape Canaveral area has a history of trawl studies for general comparison.

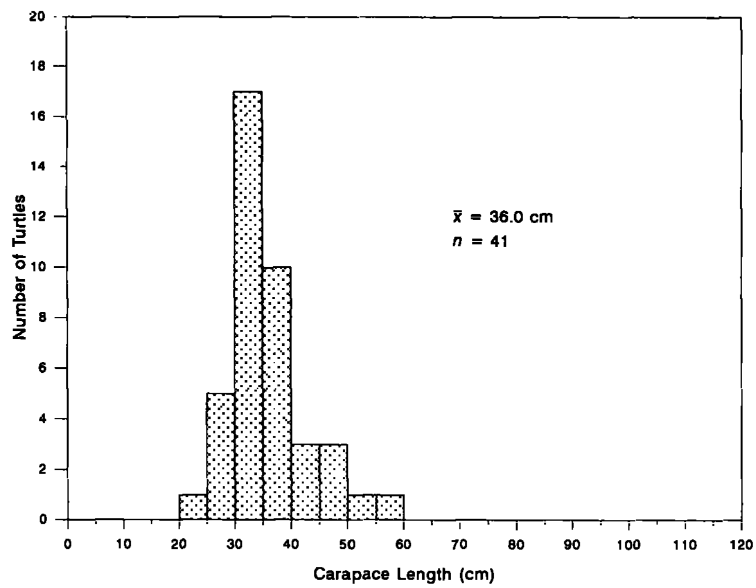

Figure 7

Length frequencies of green turtles, *Chelonia mydas*, collected along the Atlantic coast of Florida from 1986 to 1991.

Trawl surveys conducted by NMFS and the U.S. Army Corps of Engineers from 1974 to 1984 established that marine turtles, especially loggerhead turtles, aggregate in the Port Canaveral ship channel. Henwood (1987a) reported a loggerhead CPUE of 2.00 to 4.86 turtles/hour from July to October 1980, increasing to 12.05 turtles/hour in November. Butler et al. (1987) noted that mean CPUE by month was greater than 10 loggerhead turtles/hour from November 1981 to March 1982 and that there were lower CPUE values from April to September 1982. The CPUE values cited from the previous studies are greater than those in the present analysis, which may be attributable to the different objectives of the present study and the former trawl surveys. The CPUE data presented by Henwood (1987a) were collected during trawl surveys designed to reduce turtle mortality from maintenance dredging in the Port Canaveral ship channel. Butler et al. (1987) conducted surveys of the channel to develop methods of estimating loggerhead abundance. Marine turtles were the target species in both of these studies. The CPUE values reported in this study should be viewed as representative of turtles taken in the commercial shrimp fishery of east-central Florida.

The data on loggerhead turtles collected in the present analysis are similar to the earlier investigations of Henwood (1987a). Most of the log-

Table 5

Estimated values of asymptotic length (a) and intrinsic growth rate (K) from nonlinear regression of von Bertalanffy growth interval equation for Kemp's ridley turtles (one asymptotic standard error in parentheses).

Data treatment	*n*	*a*	*K*
All recaptures	12	61.11 cm	0.0577
		(5.43)	(0.2176)
	Residual mean square error = 3.4359		
Capture and recapture by contract vessel	10	60.81 cm	0.5943
		(5.76)	(0.2439)
	Residual mean square error = 4.1701		
All recaptures >90 days	6	60.66 cm	0.6037
		(8.04)	(0.3549)
	Residual mean square error = 8.2325		
All recaptures >180 days	3	77.85 cm	0.2466
		(21.09)	(0.1770)
	Residual mean square error = 1.1478		

Table 6

Monthly and yearly trawl captures of green turtles, *Chelonia mydas*, in the nearshore waters of Florida. Dashes indicate trawling effort outside of the study area.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1986					1	0/—	—	—	—/0	0	0	2	3
1987	7	1	0	1	0	0/—	—	—	—	—/0	0	6	15
1988	0	0	0	0	0	0	0	0	1	0	0	2	3
1989	4	0	0	0	0	3	0	0	0	0	1	0	8
1990	0	0	0	0	0	0	0	0	1	3	5	3	12
1991	0	0	0	0	0	0	0	0	—	0	0	0	0
Total	11	1	0	1	1	3/—	0/—	0/—	2/—	3/—	6	13	41

gerhead turtles captured on the east-central coast of Florida were mid-subadults (50–70 cm), typical of immature loggerhead turtles in the western Atlantic Ocean. There was a shift to a larger size class during the spring and summer, a period when reproductively active adults immigrate to the nesting beaches of southeast Florida (Henwood, 1987a). At that time, some immature loggerhead turtles emigrated to foraging grounds as far north as Chesapeake Bay. Captures of adult loggerhead turtles in the coastal waters of Florida declined by late summer with the end of the nesting season. Conversely, the presence of subadult loggerhead turtles increased with the onset of winter.

Kemp's ridley turtles in the northwestern Atlantic are transported from their natal beaches in Mexico by major oceanic currents in the Gulf of Mexico (Collard and Ogren, 1990). The smallest Kemp's ridley turtles captured on the east coast of Florida coincide with the minimum size class for postpelagic turtles in the Gulf of Mexico (Ogren, 1989). Skeletochronological age estimates indicate that these turtles may be two years old (Zug and Kalb, 1989), which may indicate the length of this species' pelagic developmental stage. Recapture data from the present analysis and that of Henwood and Ogren (1987) suggest that Kemp's ridley turtles on the Atlantic coast overwinter in the Cape Canaveral area and migrate to northern foraging grounds during the summer. The lack of significant numbers of adult turtles in the northwestern Atlantic suggests that Kemp's ridley turtles migrate from the U.S. east coast upon reaching sexual maturity. Recently, a Kemp's ridley turtle captured and tagged on the southeast coast of Florida was observed nesting in the western Gulf of Mexico.[10]

Relatively low numbers of green turtles have been captured in the Cape Canaveral area. This observation may be the result of this species preference for a habitat other than the Port Canaveral ship channel and adjacent areas of shrimp trawling. Capture data from fishery-independent studies indicate that early subadult (20–40 cm) green turtles inhabit the nearshore reef tracts off the southeast coast of Florida (Ernest et al., 1989; Wershoven and Wershoven, 1989, 1992; Guseman and Ehrhart, 1990). A slightly larger size class of green turtle was captured on the seagrass shoals of the Indian River Lagoon system (Mendonça and Ehrhart, 1982). Seventy-eight percent of the 108 green turtles captured in Mosquito Lagoon were greater than 40-cm carapace length. Furthermore, green turtles captured in the Indian River Lagoon, south of Sebastian Inlet, were significantly larger than those collected on the reefs offshore of Vero Beach (Guseman and Ehrhart, 1990).

There are a number of problems with the growth data presented in this paper. Extrapolating yearly growth rates from short-term recaptures amplifies measurement error. Extremely large and negative growth values were usually the result of short intervals between capture and recapture. Differences in the measuring techniques used by other investigators was a major source of error when computing growth rates. Length measurements are often reported as "straight-line carapace length" when, in fact, there are four possible straight-line carapace lengths: total, standard, notched, and minimum (Pritchard et al., 1983). Standardized methods of measurement, or a definition of the measurement technique and accurate conversions between the various techniques, are necessary for comparisons between studies (Bjorndal and Bolten, 1988). The growth models presented in this analysis should be interpreted cautiously given the forementioned problems with the database.

In conclusion, the results of this study are indicative of the importance of east-central Florida as a developmental habitat for three species of marine

[10] Martin, E. Applied Biology, Inc., P.O. Box 974, Jensen Beach, FL, 34958. Personal commun., 1994.

turtle. The Cape Canaveral aggregation of loggerhead turtles is composed of significant numbers of subadults. Furthermore, the east coast of Florida supports the second largest rookery for this species (Ross, 1982). Subadult Kemp's ridley and green turtles appear to overwinter in the Cape Canaveral area. The eastern seaboard of North America serves as a vital link between the pelagic stage of marine turtle development and recruitment to the coastal-benthic foraging stages. Continued research in coastal waters is essential to the conservation of these threatened and endangered species.

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