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Kemp's Ridley Sea Turtle Movements and Migrations

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ABSTRACT. – The Kemp's ridley, *Lepidochelys kempii*, is the most endangered of all sea turtles. It is distributed throughout the Gulf of Mexico and occurs along the eastern seaboard of North America to Nova Scotia. Isolated occurrences have been documented in the eastern north Atlantic and Caribbean. Its presence in U.S. waters is seasonal, with sea water temperature playing an important role in the distribution of the species. In the Gulf of Mexico, Kemp's ridleys arrive at northern coastal feeding areas in the spring and migrate south in the fall. Occurrence on the east coast of North America is more common during June, July, and August. Kemp's ridleys are typically found in water depths < 20 m from April through September, and they move out to 50-m depths during October through March. Movement year-round appears to be nearshore (within 18 m) and parallel to shorelines. Mean submergence duration of Kemp's ridleys is > 30 min in the winter and less than 15 min during other seasons. Single dive durations range from less than 1 min to over 4 hrs. Kemp's ridleys spend up to 96% of their time submerged. Mean movement of satellite- and radio-tracked turtles was 26.6 and 8.8 km/day, respectively.

KEY WORDS. – Reptilia; Testudines; Cheloniidae; Lepidochelys kempii; sea turtle; seasonal migration; telemetry; movements; diving bebavior; USA

The Kemp's ridley, *Lepidochelys kempii* (Garman, 1880), is an endangered sea turtle (Turtle Expert Working Group, 2000). It is distributed throughout the Gulf of Mexico and occurs along the eastern U.S. seaboard to Nova Scotia, Canada (Hay, 1908; Hildebrand, 1982; Lutcavage and Musick, 1985; Henwood, 1987; Keinath et al., 1987; Pritchard, 1989; Márquez, 1994; Epperly et al., 1995b). Very limited occurrences of this species have been reported from European Atlantic waters (Deraniyagala, 1938; Taylor, 1963; Fontaine et al., 1989), the Mediterranean (Pritchard and Marquez, 1973), Morocco (Manzella et al., 1988), the Azores (Bolten and Martins, 1990), Bermuda (Mowbray and Caldwell, 1958), Jamaica (Dunn, 1918) and Nicaragua (Manzella et al., 1991).

Understanding habitat needs of sea turtles is recognized as essential to the recovery of sea turtle stocks in the Atlantic and Gulf of Mexico (Thompson et al., 1990). Electronic tracking can provide information on locations of turtle foraging and nesting areas, submergence dynamics (number, duration, and depth of dives), diurnal behavior, ambient temperature, and social interactions. This paper reviews information on the movement of Kemp's ridley sea turtles obtained during studies by the National Marine Fisheries Service (NMFS), Galveston Laboratory, between 1988 and 1996.

METHODS

Seasonal foraging areas of Kemp's ridleys in the northwestern Gulf of Mexico (Bolivar Roads and Sabine Pass, Texas, and Calcasieu Pass, Louisiana; Fig. 1.) were the focal areas of our study. Bolivar Roads, located at the north end of Galveston Island, is the entrance to Galveston Bay and the Houston Ship Channel. Jetties at this pass are 2.6 km apart at their widest and extend 7.5 km into the Gulf. Sabine Pass, on the Texas-Louisiana border, is the entrance to Sabine Lake and the Sabine-Neches Waterway serving Port Arthur, Texas. Jetties at Sabine Pass are 600 m apart at their widest and extend 5.3 km into the Gulf. Calcasieu Pass jetties protect the entrance to Lake Calcasieu and Calcasieu River that serve the port of Lake Charles. These jetties are 305 m apart at their widest and reach 1.9 km into the Gulf. We also monitored Kemp's ridleys in Lavaca Bay, Texas, and on the U.S. seaboard from Florida to North Carolina.

Kemp's ridleys were captured using entanglement nets set at locations along jetties and from nearshore areas of the upper Texas and western Louisiana coasts (A. Landry, Texas A&M University at Galveston, unpubl. data). Following capture, turtles were transported to land-based holding stations where they were held up to 96 hrs for collection of morphometric data, assessment of physical well being, and tagging purposes. Standard straight and curved carapace length (SCL, CCL) and carapace width (SCW, CCW) were measured to the nearest 0.1 cm. Weight was measured to the nearest 0.1 kg using an electronic hanging scale. An Inconel tag was applied to both front flippers while a PIT (Passive Integrated Transponder) tag was injected to the right front flipper. Also, Kemp's ridleys obtained opportunistically from shrimp trawls, gill nets, or hook and line, as well as rehabilitated stranded turtles, were used in this study.

Radio transmitters (164.0–165.0 MHz) were fiberglassed to the anterio-medial scutes of turtles, and sonic transmitters

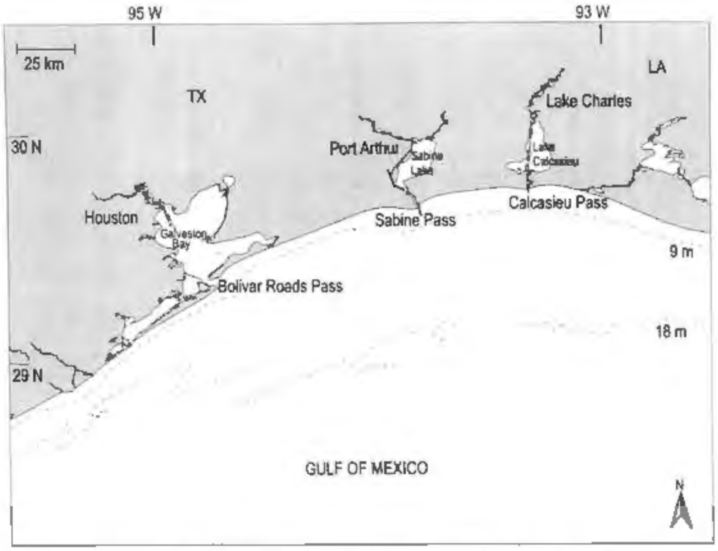


Figure 1. Major study areas: Bolivar Roads and Sabine Pass, Texas, and Calcasieu Pass, Louisiana.

(30–81 KHz) were wired through the most posterior marginal scute. Radio transmitters were monitored using a Telonics TR2/TS1 receiver/scanner connected to a directional 5-element Yagi antenna. Sonic transmitters were monitored using a Sonotronics directional hydrophone with a receiving range from 2–5 km. Radio monitoring alone occurred from land when weather prohibited tracking on water. With a few exceptions, data were collected daily, between 0600 and 1800 hrs. Identification of each turtle's location was attempted every 1 to 2 days. Visual sightings of radio-tracked sea turtles, or their positions as determined by sonic telemetry, were recorded using a Global Positioning System (GPS; ± 100 m error). The most accurate positions were based on visual sightings. Sonic telemetry provided the second-most accurate position (using sonic telemetry, we found that experienced technicians easily can direct a vessel to within 5 m of a sea turtle). Locations determined by radio-triangulation were the least accurate. All radio tracking was conducted from May through December.

A variety of satellite transmitters (Platform Transmitter Terminal or PTT) were used during these studies. Data were transmitted (401.65 MHz, 50 sec pulse interval) at alternating 6-hr periods for the life of the PTT batteries. Depending on the satellite tag, data from PTT transmissions could include 1) PTT identification number, 2) latitude and longitude, 3) location reliability index, 4) date and time, 5) number of dives made during specified 12-hr periods, 6) average dive duration, and 7) duration of last dive. Service Argos Inc. collected data transmissions from NOAA satellites. Following the application of electronic tags, all turtles were released within 1 km of their capture site. Use of externally placed tags on sea turtles is a safe, proven technique (Renaud et al., 1993), when applied according to the conservative rule that tag weight not exceed 10% of the turtle's body weight (Byles and Keinath, 1990). Our studies used a 5% guideline for this relationship.

The harmonic mean program Home Range (Ackerman et al., 1990) was used to calculate harmonic mean home range areas. Core area, a central region which receives consistent or intense use (Kaufmann, 1962), was the maximum area in which observed turtle distribution exceeded a uniform distribution. To increase independence between locations, only one location per day was retained for analysis for each turtle.

Locations of radio- and satellite-tracked turtles were plotted on NOAA nautical charts to determine distance from shore and water depth for each turtle position. Rate of movement by sea turtles was standardized to distance traveled per 24-hr period. Mean submergence time and percent of time spent under water (percent submergence) were calculated for each turtle, when possible. The fall and winter movements of Kemp's ridleys were monitored in response to changing seawater temperature using AVHRR (Advanced Very High Resolution Radiometer) and satellite telemetry.

RESULTS

Between 1988 and 1996, NMFS Galveston Lab personnel tracked 106 Kemp's ridleys in the Gulf of Mexico and along the U.S. Atlantic coast using satellite ($n = 52$) and/or radio and sonic telemetry ($n = 59$); 5 were tagged with both satellite and radio tags. Most (97) were captured and released offshore. Their movements were monitored up to 66 days with radio telemetry (mean = 25 d) or to 453 d with satellite telemetry (mean = 100 d). Turtles ranged in size between 2–43 kg and 26–66 cm SCL and were placed into two size categories, small (< 50 cm SCL) and large (≥ 50 cm SCL). All small turtles were juveniles; large turtles included subadults and adults (Márquez, 1994).

Kemp's ridleys captured at Bolivar Roads, Sabine Pass, and Calcausieu Pass which remained within 15 km of their capture site for at least 50% of the tracking days were designated as habitat faithful. Only juvenile turtles ($n = 78$) occupying seasonal foraging areas comprised this category. This behavior occurred during the spring and summer and was associated with seasonal foraging areas. Fifty-seven

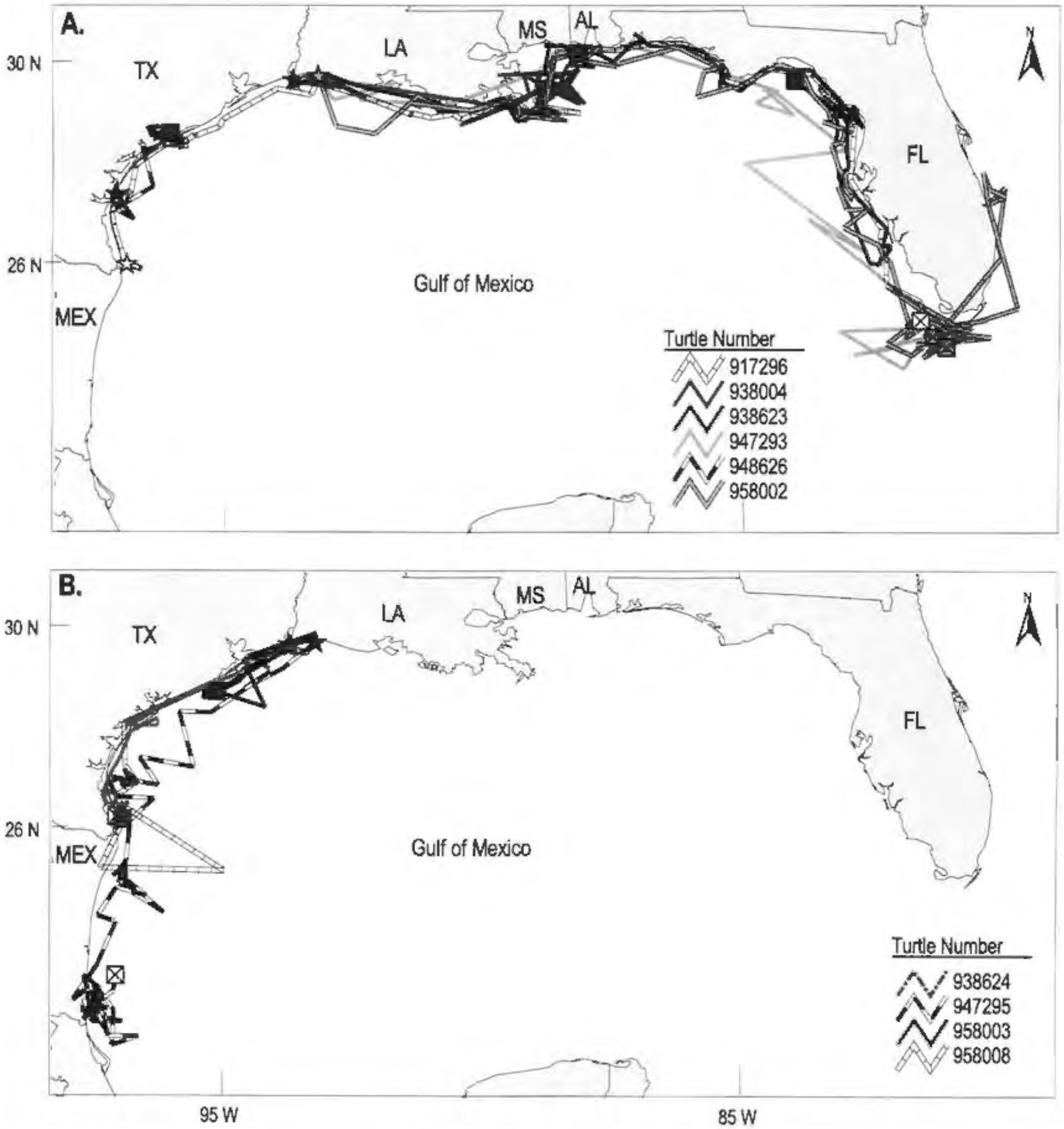


Figure 2. Migrational movement of large (> 25 kg) Kemp's ridleys. **A.** Easterly movement. **B.** Westerly movement. Release point of turtle is marked with a star; endpoint of tracking is marked with an X in a box.

(73%) of these juveniles remained within 10 km of their release site during the months of May through September. The locations of sixty (77%) turtles fell within 15 km of their release sites during the same time period. Although turtles wandered from these "preferred" areas, they often returned to them.

Eighteen juvenile and 11 subadult and adult (> 50 cm SCL) Kemp's ridleys were not habitat faithful. None remained within 15 km of their release site. Juveniles moved 20–80 km from their release site, with this movement occurring between Sabine and Calcasieu Passes, and between Calcasieu Pass and Mermentau Pass, Louisiana. Subadult and adult turtles

Table 1. Mean daily distance traveled (km/d ± Standard Error, and sample size (*n*; in parentheses) by satellite-tracked Kemp's ridley sea turtles in the Gulf of Mexico. A horizontal line beneath mean km/d indicates that no significant difference (ANOVA, $\alpha \geq 0.05$) was present among those seasons.

Size Groups	All Data	Spring (Mar-May)	Summer (Jun-Aug)	Fall (Sep-Nov)	Winter (Dec-Feb)
Small Turtles (juveniles) (< 50 cm SCL)	24.2 ± 1.3 (895)	62.9 ± 12.2 (34)	22.4 ± 1.5 (525)	18.0 ± 2.2 (239)	5.4 ± 4.4 (97)
Large Turtles (subadults/adults) (≥ 50 cm SCL)	28.8 ± 1.2 (964)	25.5 ± 2.4 (167)	33.4 ± 3.1 (175)	25.9 ± 2.0 (340)	31.3 ± 2.2 (282)

Table 2. Mean daily distance traveled (km/d ± Standard Error, and sample size (n; in parentheses) by radio-tracked Kemp's ridley sea turtles in the Gulf of Mexico. A horizontal line beneath mean km/d indicates that no significant difference (ANOVA, $\alpha \geq 0.05$) was present among those seasons. Differences within seasons are depicted with lettered superscripts. Identical superscripted-letters among size groups indicates no significant difference in mean km/d traveled (ANOVA, $\alpha \geq 0.05$).

Size Groups	All Data	Spring (Mar-May)	Summer (Jun-Aug)	Fall (Sep-Nov)	Winter (Dec-Feb)
26.1-32.0 cm SCL	[a]7.5 ± 1.7 (171)	[a]3.7 ± 0.9 (18)	[a]8.8 ± 2.5 (116)	[a]5.4 ± 1.3 (37)	—— (no data)
32.1-41.0 cm SCL	[a]8.3 ± 1.7 (205)	[a]8.1 ± 1.8 (18)	[a]10.7 ± 2.9 (121)	[a]4.0 ± 1.0 (65)	—— (1)
41.1-49.9 cm SCL	[a]12.0 ± 3.7 (104)	[a]14.7 ± 11.9 (13)	[a]8.0 ± 3.7 (58)	[b]18.0 ± 8.7 (33)	—— (no data)

captured during the spring and summer never remained within 5 km of their release site for more than 5 days. Capture, tagging, and release appeared to be only a minor delay in the re-establishment of their long distance movement. From release sites in Texas and Louisiana, 6 of 11 turtles moved to the east, 4 to the west, and no location data were received for the remaining turtle (Fig. 2).

Mean daily distance traveled by satellite-tracked turtles in the Gulf of Mexico was 26.6 km/d. Mean daily movement was significantly higher (28.8 km/d; t-test, $p = 0.009$) for subadult and adult turtles than for juvenile turtles (24.2 km/da; Table 1). Mean daily distance traveled for radio-tracked turtles in the Gulf of Mexico was 8.8 km/d. As a group, there were no significant differences in km/d traveled by season. Radio tracked turtles were subdivided into three size categories, 26.1–32, 32.1–41.0, and 41.1–49.9 cm SCL, to test for differences over their size range. When all seasons were combined, there was no significant difference in km/d traveled by size category. Movements in the spring and summer were similar but not statistically different among size groups. However, during the fall, daily distance traveled was significantly higher for the largest (41.0–49.9 cm SCL) size category (ANOVA, $p = 0.03$; Table 2).

Home range and core area may be used as measures of habitat faithfulness. Home range and core area for 25 satellite-tracked ridleys during the summers of 1993 and 1994 were 3200 and 1050 km^2, respectively. One-third of the home range, wherein the Sabine Pass jetties were centrally located, was used by these turtles as a core area 63% of the time (Fig. 3). During a 1996 study in Lavaca Bay, Texas (Renaud and Williams, 1997), 6 radio-tracked Kemp's ridleys exhibited a home range of 429 km^2 and a core area of 138 km^2 (64% utilization). In both studies the core area was approximately 33% of the home range and its utilization was over 60%.

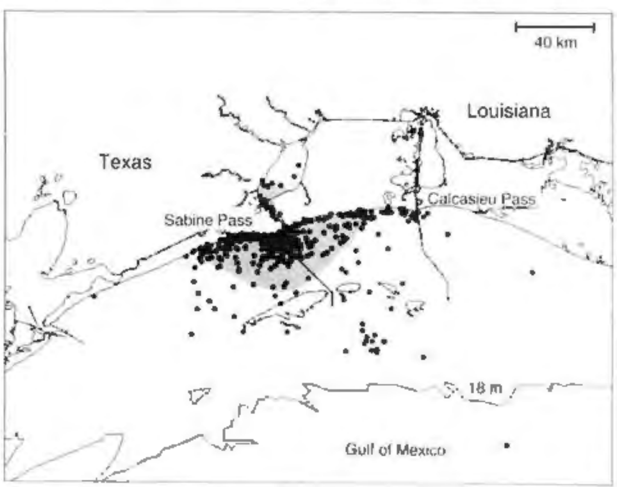
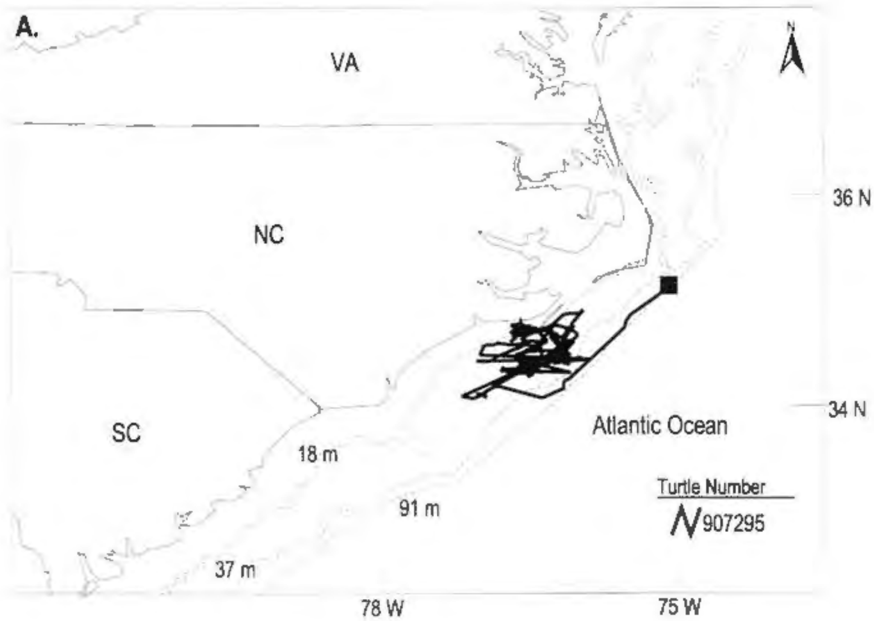


Figure 3. Core area (shading; 1050 km^2) where 63% of all locations from 25 satellite-tracked turtles were recorded during 1993 and 1994 studies.

Fall and winter movements of sea turtles were monitored in response to changing seawater temperature. During the winter of 1990–91, a Kemp's ridley released off Beaufort, North Carolina, progressively moved 50 km offshore into the Gulf Stream (Renaud, 1995; Fig. 4a). Coastal waters had dropped to between 5–10°C by the time the turtle reached the Gulf Stream where water temperature was 21°C. Five other turtles exhibited similar southerly movement during fall and winter along the east and west Florida coasts (Fig. 4b). For one turtle on the east coast, southerly movement in late January stopped just south of Cape Canaveral (Renaud, 1995). This turtle and another tracked by Gitschlag (1996) exhibited northerly movement from February through June reaching northern Georgia and South Carolina by late April. Four ridleys on the west (Gulf) coast of Florida moved in a southerly direction during the months of October through January extending into the Florida Keys. The degree of southerly movement appeared to correspond to the severity of the cold temperature. Once waters began to warm, turtles reversed their directions of movement. One turtle rounded the tip of Florida and moved northward to Sebastian Inlet, Florida, in February (Fig. 5). Its movement to the Keys, and hence the east coast of Florida, was strongly associated with the intrusion of a cold water mass along the southwestern Florida shore. Southerly and southwesterly fall and winter migrations also were observed for three turtles on the central and upper Texas coast (Fig. 6). Fall migration for two of these ridleys began shortly after the passage of cold fronts. The remaining turtle, a mature female, moved steadily south along the Texas coast, and entered Mexican waters five months after its release at Calcasieu Pass. During the next four months it nested twice at Rancho Nuevo, Tamaulipas (Renaud et al., 1996).



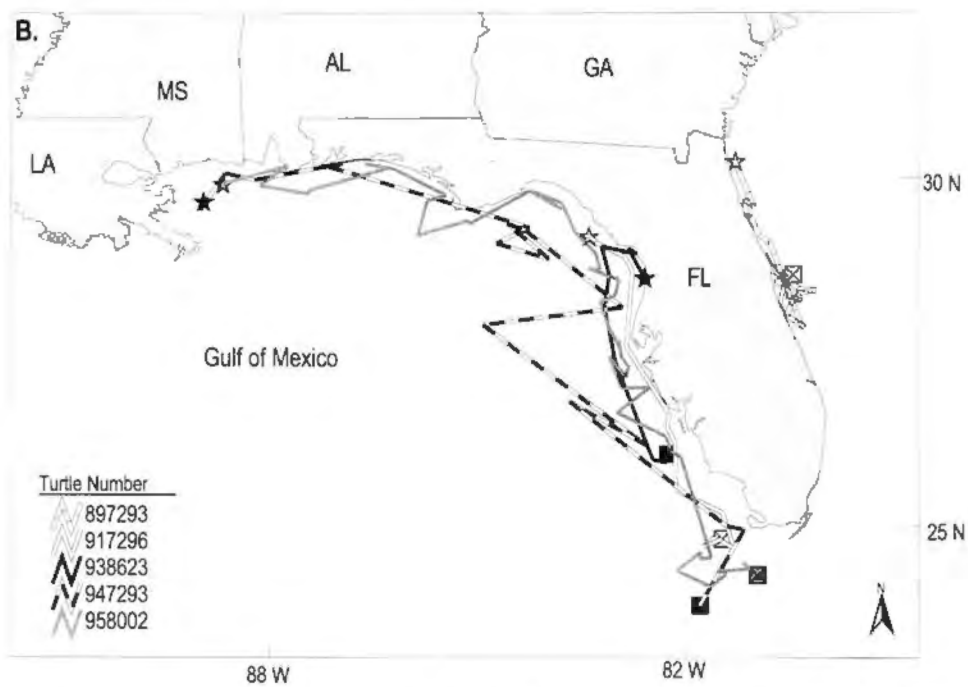


Figure 4. Fall and winter movements of satellite-tracked Kemp's ridleys (1 October through 31 January). **A.** Movement into Gulf Stream off North Carolina. **B.** Southerly migration along Florida coasts. First location in October is marked with a star; last location in January is marked with an X in a box.

Mean distance from the shore (± standard error; SE) and mean water depth (± SE) of all observed turtle positions were 12.0 ± 0.4 km and 36.4 ± 1.2 m, respectively. Ridleys were close to shore (mean = 6.6 km) and in shallow water (mean = 21.7 m) during the months of April through September. Mean values for distance from shore (22.8 km) and water depth (64.1 m) were higher during October through March. Mean submergence duration for all ridleys combined was 8.1 min, and was 5.6 ± 0.1 min for small radio-tracked turtles, 18.1 ± 1.3 min for small satellite-tracked turtles, and 33.4 ± 2.1 min for large satellite-tracked turtles. Mean submergence was higher for satellite-tracked turtles because data include prolonged winter submergences. In the winter, mean submergence durations of turtles were > 30 min. Mean submergence duration was < 15 min during other seasons. Percent submergence ranged from 69.1–96.4% among individual turtles and was 92% for all ridleys combined.

DISCUSSION

Although we conducted some work in the Atlantic, our research concentrated on the movements of Kemp's ridleys and their association with coastal habitats in Texas and Louisiana. During April through September, ridleys re-

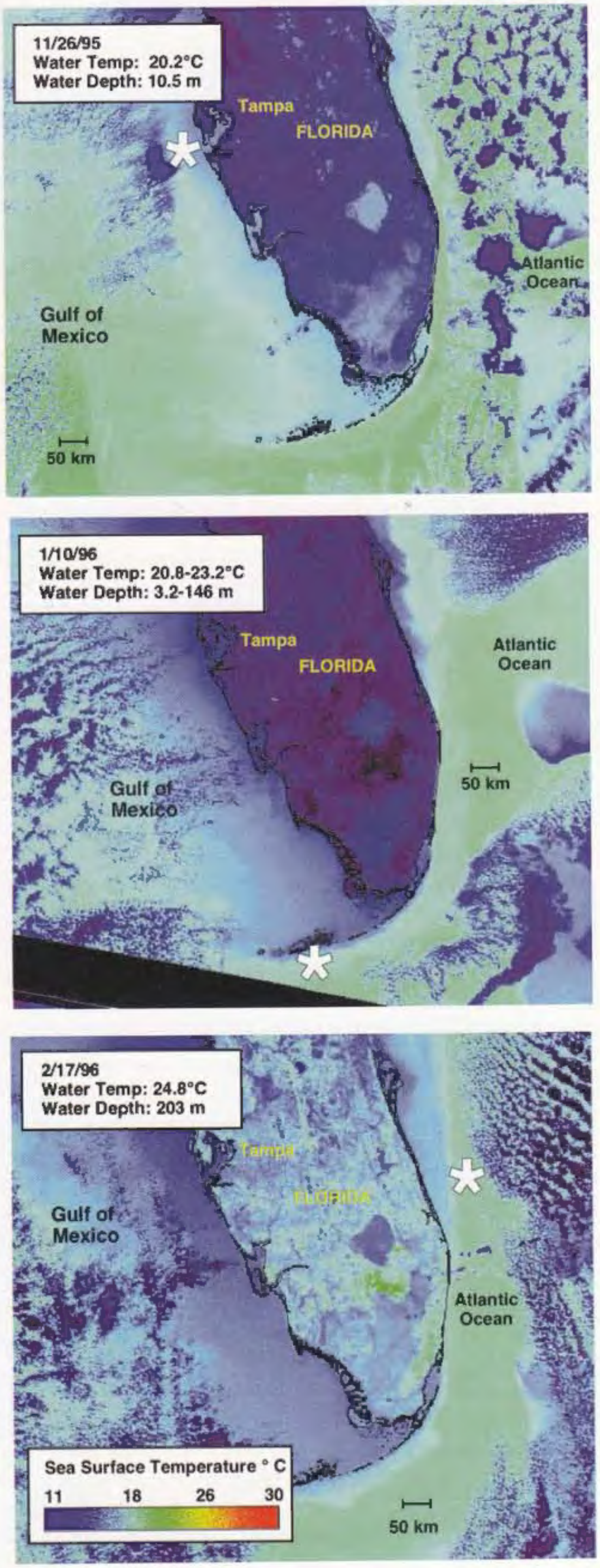


Figure 5. Time sequence of satellite imagery of sea surface temperature and movement of a single Kemp's ridley. This turtle kept out of approaching cold water masses (10–15∫C) and remained in water greater than 20∫C. The star marks the location of the turtle in each photo.

mained in shallow nearshore waters near jettied passes, or moved inshore into bay waters of the Gulf of Mexico. Nearshore foraging grounds were delineated for juvenile Kemp's ridleys within a 15 km radius of Sabine and Calcasieu Passes. Biological and physical characteristics of the habitat (food availability, bottom type, sea state, water temperature, etc.) may be responsible for the observed distribution of sea turtles. Daily locations for habitat faithful turtles were concentrated outside of the passes on the lee side of jetties at Bolivar Roads, Sabine, and Calcasieu. These areas were protected from adverse sea conditions and supported populations of blue crab, *Callinectes sapidus*, a natural food source for Kemp's ridleys (A. Landry, *pers. comm.*). Discarded commercial shrimping bycatch in these areas also offered a potentially available food source for the turtles.

Long-range migration routes were determined for juvenile and adult Kemp's ridleys along the Gulf of Mexico and Atlantic coasts. We were able to track one adult female from a foraging ground offshore of Louisiana to its nesting beach in Rancho Nuevo, Mexico, and another ridley (sex undetermined) through the Florida Straits into the Atlantic Ocean.

Migration paths of sea turtles, in conjunction with AVHRR imagery of sea surface temperatures, were used to evaluate responses of sea turtles to seasonal changes in water temperature. The passage of cold fronts in the fall reduced seawater and air temperature, and was thought to stimulate environmentally induced migrations of Kemp's ridley turtles. Although the decrease in temperature is not usually life threatening, turtles responded within days by moving out of bays, offshore, and in a southerly direction. Van Dolah and Maier (1993) found a significant correlation between loggerhead densities and water temperature in Charleston Harbor, South Carolina, suggesting that they avoid water < 16°C. Keinath et al. (1996) further substantiated the avoidance of cold water by Kemp's ridleys and loggerheads; turtles in North Carolina waters began migrating when water temperature reached 15°C. The hypothesis that juvenile and adult Kemp's ridleys move to the south and/or offshore during the fall and winter and return to estuarine environments the following spring was supported by our data.

With the exception of offshore movement in the winter, movements of juveniles and adults remained close to coastlines. Over periods of 9–18 months, large juveniles and adults traveled up to 2600 km along the Gulf of Mexico and Atlantic coasts, mainly within the 18-m depth contour. Movements of small turtles during the spring and summer were typically within a range of < 15 km of a nearshore foraging location. Small turtles tracked through the winter with satellite tags traveled up to 200 km from their release site. Net linear coastal movement was low for juvenile turtles compared to that for subadult and adult turtles.

Submergence duration for Kemp's ridleys (1 min to 4 hrs) had a greater range than that described for olive ridley (10 sec to 95 min; Beavers and Cassano, 1996), green (1 sec

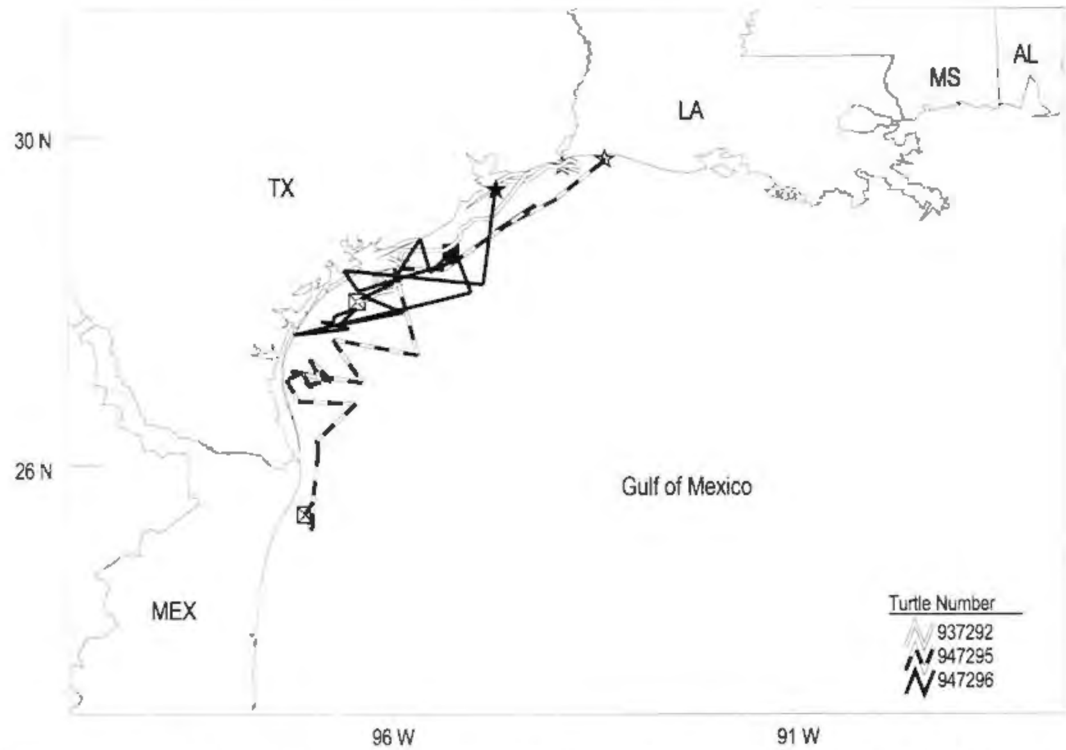


Figure 6. Winter movements of satellite-tracked Kemp's ridleys in the western Gulf of Mexico (1 October through 31 January). A turtle's first location in October is marked with a star, and its last location in January is marked with an X in a box.

to 26 min; Renaud et al., 1995), loggerhead (4.2–171 min; Renaud and Carpenter, 1994), and hawksbill sea turtles (34–73 min; Starbird and Hillis, 1995). Mean percent submergence of Kemp's ridleys (92%) was similar to that of adult green (96%, Balazs, 1994), adult Kemp's ridley (96%, Byles, 1989), juvenile loggerhead (96%, Kemmerer et al., 1983; 93%, Renaud and Carpenter, 1994), and olive ridley sea turtles (88%, Byles and Plotkin, 1994).

Research on Kemp's ridley movement, migration behavior, and distribution using electronic tracking has steadily increased since 1988. Morreale and Standora (1991, 1992), Morreale et al., (1988, 1992), and Standora et al. (1989, 1990, 1991) have studied Kemp's ridley movement, feeding, and cold stunning in Long Island Sound, New York. Byles (1988) reported on movement of adult female Kemp's ridleys to the Yucatan Peninsula, Mexico, and into U.S. waters from their nesting beach at Rancho Nuevo, Tamaulipas. Gitschlag (1996) reported on Kemp's ridley movement between South Carolina and Florida from October 1991 through July 1992. Also, other methodologies have been used to document sea turtle movements and distribution. Mark-recapture is inexpensive and permits the tagging of many specimens. Fontaine et al. (1993) described external flipper tags, external living tags, internal PIT tags, and magnetic wire tags used in the Kemp's ridley headstart program at NMFS Galveston. Tags have been returned from as far away as Europe in the east and Nicaragua in the south (Manzella et al., 1988, 1991). External flipper tags have been applied to Kemp's ridleys at nesting beaches in Rancho Nuevo, Tamaulipas, for nearly 35 years (Turtle Expert Working Group, 2000). Henwood and Ogren (1987), Márquez et al. (1989), and Schmid (1995) also have employed external flipper tags to study Kemp's ridley movements. Schmid (1995) cited the first occurrence of a Kemp's ridley nesting in Mexico that had been tagged in the Atlantic (southeast coast of Florida). Epperly et al. (1995a, b, c; 1996) worked at length to determine sea turtle distribution along the North Carolina coast, using aerial surveys, surveys of the summer flounder fishery, and sea turtle stranding data.

Despite these efforts, accumulation of information on movements and migrations of Kemp's ridleys has been slow, compared to other species of sea turtles. This is due in part to their restricted distribution, and difficulty in obtaining adequate numbers for research. As the population size of Kemp's ridley sea turtles hopefully continues to increase during the next decade, as indicated by recent population trends at the nesting beach in Rancho Nuevo, it is essential that managers continue to have up-to-date information so the behavior and habits of this endangered species can be evaluated.

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