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Seasonal Migrations of Immature Kemp's Ridley Turtles (*Lepidochelys kempii* Garman) Along the West Coast of Florida

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Six immature Kemp's ridley turtles (*Lepidochelys kempii*) were monitored via satellite telemetry to investigate their winter migration on the west coast of Florida. All turtles departed from Cedar Keys in late Nov., migrated southward in Dec., and overwintered in offshore waters from Anclote Keys to Captiva Island during Jan., 120 km and 296 km from Cedar Keys, respectively. Turtles migrated northward in Feb. and began returning to Cedar Keys in March. Five of the turtles occupied relatively small (3.8–48.0 km^2) postmigration foraging ranges through Aug. The sixth turtle returned to Waccasassa Bay, east of Cedar Keys, but locational data were insufficient for postmigration analysis. Mean sea surface temperature (SST) used by turtles in Nov. decreased from 23.6 ± 1.9 C during the first 2 weeks to 17.1 ± 1.5 C during the latter 2 weeks, and corresponded to their departure from Cedar Keys. Mean SST used by turtles in Jan. increased from 14.0 ± 1.6 C during the first 2 weeks to 16.6 ± 1.4 C during the latter 2 weeks, and corresponded to the onset of their northward migration. Turtles traveled up to 13–56 km offshore to maximum depths of 15–31 m. Higher proportions of satellite location classes requiring four or more uplinks were obtained during winter months suggesting that turtles spent more time at the surface during their migrations. Further studies are needed to determine possible size-specific differences in depth use and migration patterns, to identify benthic habitats used by Kemp's ridleys during winter migrations, and to determine what anthropogenic impacts occur within their migratory routes along the Florida coast.

The Kemp's ridley, *Lepidochelys kempii* Garman, is considered to be the most endangered species of marine turtle and is distributed throughout the Gulf of Mexico and northwestern Atlantic Ocean (National Research Council, 1990). Immature turtles inhabit coastal waters from Massachusetts to Texas. At the onset of winter, turtles occurring in temperate latitudes may either move to warmer waters or remain in the area and possibly strand or perish if water temperature falls below a critical level (10–13 C; Schwartz, 1978). Carr and Caldwell (1956) first noted turtle fishermen's reports that Kemp's ridley and green turtles, *Chelonia mydas* Linnaeus, assemble in the Cedar Key–Crystal River area of western Florida as preparation for a mass seasonal migration in the fall. However, some of the fishermen believed the assemblage was a prelude to "burying up" in mud-bottom holes and remaining in the area throughout winter. Observations of torpid loggerheads, *Caretta caretta* Linnaeus, captured in the Port Canaveral ship channel, and thermal data indicating that these turtles had been embedded within the walls of the channel, provided support of brumation by some of the turtles in this eastern Florida aggregation (Carr et al., 1980; Ogren and McVea, 1982).

Subsequent tagging and telemetry studies have identified Cape Canaveral as an important overwintering area for Kemp's ridleys and demonstrated a seasonal migration along the U.S. Atlantic seaboard. Capture data suggest Kemp's ridleys occur in this area primarily during the winter months (Henwood and Ogren, 1987; Schmid, 1995). Furthermore, turtles tagged off the east coast of Florida during the winter were recaptured in northeastern U.S. waters during the summer, and turtles tagged in northeastern waters during summer were recaptured off Florida in winter. Satellite telemetry has been used to document Kemp's ridleys migrating southward in response to decreasing water temperatures. Immature turtles depart from New England waters in fall and continue southward off the coast of North Carolina (Morreale and Standora, 1998, 2005). Some turtles continue migrating south and overwinter off east-central Florida, and then return northward the following spring (Renaud, 1995; Gitschlag, 1996).

By comparison, nothing is known about the winter movements of Kemp's ridleys inhabiting the west coast of Florida. Kemp's ridleys are captured in the Cedar Key area from April to Nov. (Carr and Caldwell, 1956) when water temperatures are above 20 C (Schmid, 1998).

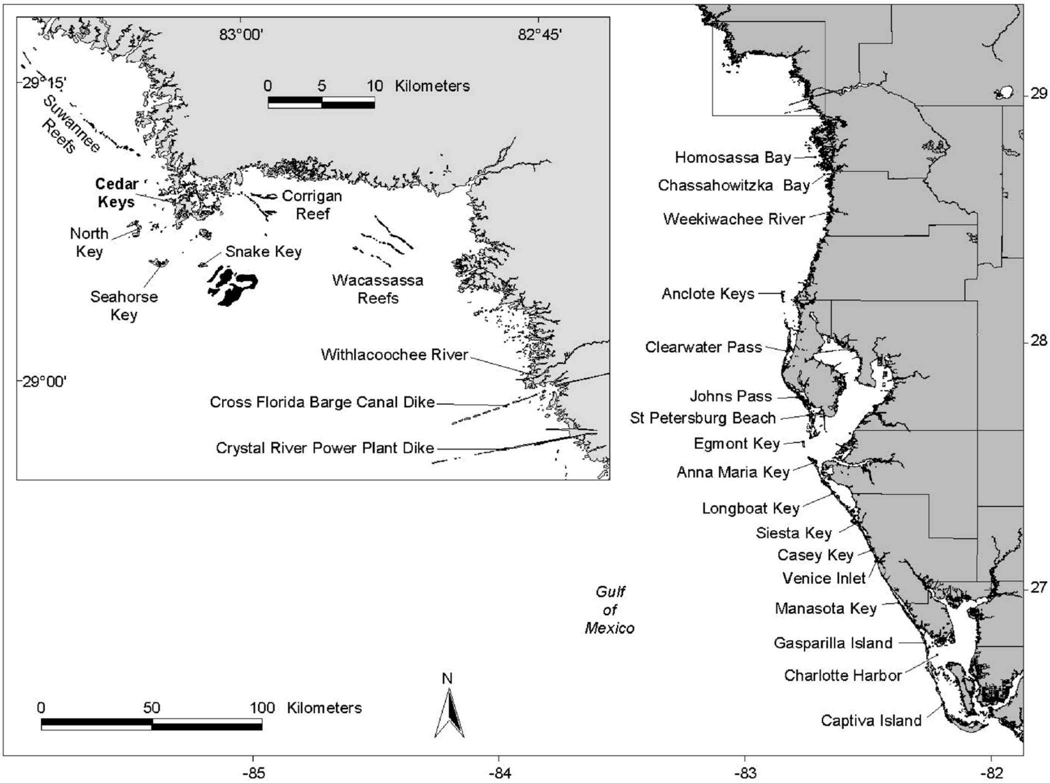

Fig. 1. Map of the west coast of Florida and the Cedar Keys study area (inset) with localities identified during Kemp's ridley migrations.

Local fishermen have contended that turtles overwinter in Cedar Keys based on the observations of turtles with muddy carapaces captured in the spring (Carr and Caldwell, 1956). Alternatively, turtles may move to warmer waters offshore, as suggested by the capture of turtles in deeper waters during winter (Ogren, 1989; Rudloe et al., 1991), or may move to warmer coastal waters to the south. There have been no tag recoveries that indicate seasonal migration along the west coast of Florida (Schmid, 1998). The eastern Gulf is an important developmental region for the Kemp's ridley (Schmid and Barichivich, 2004; Witzell and Schmid, 2004), and information on winter movements and habitat use is needed to adequately manage this critically endangered species (Thompson et al., 1990; USFWS and NMFS, 1992). The purpose of our study was to investigate the seasonal migrations of Kemp's ridleys in the coastal waters of western Florida using satellite telemetry data, sea surface temperature imagery, and bathymetric information.

Materials and Methods

Data collection.—Kemp's ridley turtles were captured in Waccassasa Bay, east of the Cedar Keys, Florida, on 15–17 Oct. 2000 (Fig. 1). A detailed description of the area is provided by Schmid (1998). Turtles were captured near Corrigan Reef (29°08′N, 82°59′W) with a 20.5-cm stretch-mesh nylon strike net and transported to a shoreside facility for processing. Standard straight-line carapace length (SSCL; nuchal notch to tip of postcentral scutes) was measured to the nearest 0.1 inch with forester's calipers, and mass was measured to the nearest 0.25 lbs with a spring scale. Measurements were converted to metric for analyses. Turtles were tagged with an Inconel tag on the right front flipper and a passive integrated transponder (PIT) tag was inserted in the left front flipper. Algae and other fouling materials were cleaned from the carapace with a medium-abrasive scrub pad. Satellite transmitters (ST-18 Model A-800; Telonics, Mesa, AZ) were mounted on the second vertebral scute with a silicone elastomer compound to provide a lev-

TABLE 1. Morphometrics and tracking summaries for Kemp's ridley turtles from the Cedar Keys area that were observed migrating along the west coast of Florida. SSCL = standard straight-line carspace length.

Turtle ID	SSCL (cm)	Mass (kg)	Maximum distance traveled (km)	Maximum distance offshore (km)	Maximum depth (m)
LK1	45.6	11.6	196	40	23
LK2	40.0	8.4	214	38	17
LK3	44.6	12.2	120	56	25
LK4	38.0	7.5	161	38	20
LK5	42.8	11.3	296	16	15
LK6	51.1	17.7	247	52	31

el base. Polyester resin and fiberglass cloth were then applied across the transmitter to secure the unit to the carapace. The turtles were released near the capture site within 6–9 hr.

The dimensions of the satellite transmitters were 14.0 × 4.8 × 3.3 cm and each weighed 275 g. The mass of the transmitter was less than 4% the mass of the smallest turtle (Table 1). The antennas were reinforced with plastic tubing to minimize damage and were oriented 45° forward for optimal signal transmission. Saltwater switches were located on the anterior face of the unit. The units were programmed to provide location data with an active duty cycle between 0600–1200 hr, when satellites were scheduled to be overhead. Location data were processed through Systems Argos, Inc. (Largo, MD) using the auxiliary location processing (ALP) service. Argos designates location classes (LC) based on the number of messages, or uplinks, received during a satellite pass. Locations calculated from at least four messages are assigned LC 3, 2, 1, and 0. Estimated accuracy in latitude and longitude is <150 m for LC 3, between 150 and 350 m for LC 2, between 350 and 1,000 m for LC 1, and >1,000 m for LC 0. ALP provides location estimates for LC A (three messages) and LC B (two messages), but these classes are not assigned estimates of accuracy.

Sea surface temperature (SST) data were obtained from the CoastWatch Gulf of Mexico Regional Node web site (http://www.mslabs.noaa.gov/cwatch/data.html). SST estimates were derived from the five-channel advanced very high resolution radiometers (AVHRR) on the National Oceanic and Atmospheric Administration's (NOAA's) polar orbiting satellites. Bathymetric data for west Florida were obtained from the National Geophysical Data Center Coastal Relief Model (National Geophysical Data Center, 2001) and shoreline data were obtained from the *Florida Atlas of Marine Resources* (Florida Marine Research Institute, 1998).

Data analysis.—Recent studies of marine animals have shown that the accuracy of LC A locations is comparable to that of LC 1 locations (Hays et al., 2001; Vincent et al., 2002). We therefore included LC A locations in our analyses. The distance of turtle locations from the southernmost tip of Corrigan Reef (Cedar Keys) was calculated using the nearest features extension (Jenness, 2001) for ArcView geographic information system (GIS) software (Environmental Systems Research Institute, Inc., Redlands, CA). Distance of turtle locations to geographic locations along the Florida coast was calculated with the measure distance tool in ArcView. Tracks between sequential locations were plotted using the animal movement extension (Hooge et al., 1999). The animal movement extension was also used to analyze postmigration foraging ranges of turtles. Given the potential for location inaccuracy, the harmonic mean outlier removal method was used to remove 25% of the locations for each turtle after it had returned to the Cedar Keys area. The minimum convex polygon home range method was then used to calculate a foraging range for the remaining locations of each turtle.

Location data for each turtle were overlaid on the SST and bathymetry base maps, and the ArcView spatial analyst extension was used to calculate estimates of SST and depth at each location. Cloud-contaminated pixels in SST images were identified using a threshold value of 5 C, because water temperatures at or below this value are considered lethal to marine turtles (Schwartz, 1978). Omitting cloud-covered locations would have severely limited the available data. Therefore, if cloud cover obstructed the SST at a turtle location, imagery no more than 3 days before or after the date of the location was used for estimation. Mean SST and depth used by turtles were compared with the Kruskal–Wallis test (SAS Institute, 1999) given the nonnormality of the data. Linear regression and Pearson correlation coefficient (r) were used to test the associations between variables. Means are followed by ±one standard deviation.

RESULTS

Movement and migration.—Kemp's ridley No. 1: LK1 was captured 15 Oct. and located in the

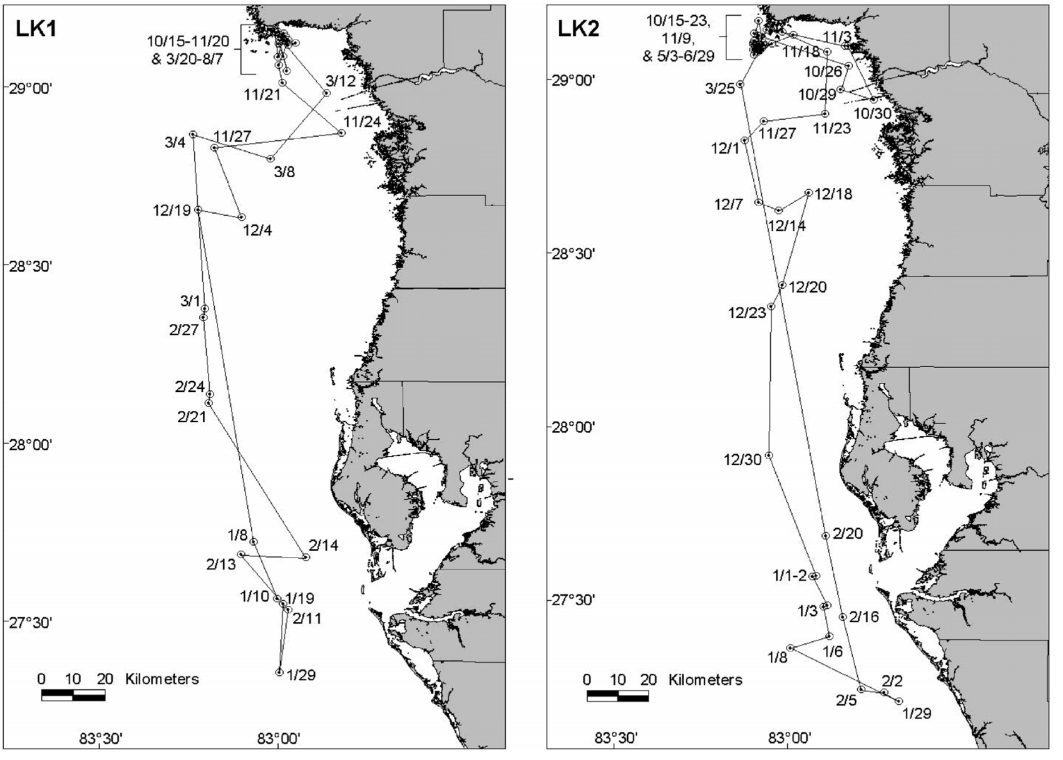

Fig. 2. Locations of Kemp's ridleys LK1 and LK2 along the west coast of Florida.

vicinity of Corrigan Reef through early Nov. The turtle began moving southward on 21 Nov. (Fig. 2), but turned southeast to an area approximately 7 km south of Crystal River Power Plant dikes on 24 Nov. before continuing offshore and southward through early Jan. Southward progression slowed 23 km offshore Egmont Key and LK1 was located in this area 10–19 Jan. Southernmost migration was 31 km offshore Longboat Key on 29 Jan. The turtle returned to the area off Egmont Key by 11 Feb. LK1 moved northward through early March, though progression slowed 35 km west-southwest of Anclote Keys on 12–24 Feb. and 39 km northwest of Anclote Keys on 27 Feb.–1 March. The turtle continued north then east to within 4 km of the Cross Florida Barge Canal dikes by 12 March. LK1 returned to Corrigan Reef by 20 March and was located in the vicinity until moving 9 km south on 29–30 March. The turtle returned to the reef complex on 21–28 April before moving 5 km south on 5 May. These southern movements were to a series of shoals located southeast of Snake Key (Fig. 1). The turtle returned to Corrigan Reef on 9 May and was located through early Aug. when contact was lost. LK1 occupied a postmigration foraging range of 13.1 km^2.

Kemp's ridley No. 2: LK2 was captured at Corrigan Reef on 15 Oct., but moved to the southwest off Seahorse Key the next day (Fig. 2). The turtle then moved northward to an area northwest of Cedar Keys by 18 Oct. LK2 moved southeastward from 23–30 Oct. to an area just south of the dikes to the Crystal River Power Plant. The turtle moved northwestward to Cedar Keys by 9 Nov. and then southward from 18–23 Nov. to 23 km offshore the power plant dike. LK2 continued slow movement offshore in late Nov. and then southward in early Dec., pausing approximately 35 km offshore Chassahowitzka Bay from 7–18 Dec., and then moved rapidly southward to 15 km offshore Egmont Key by 1 Jan. Southward movement by the turtle slowed through early Jan. and southernmost migration was 13 km offshore Siesta Key on 29 Jan. The turtle then moved slowly off the coast and northward to 14 km offshore Anna Marie Key on 16 Feb. LK2 progressed steadily northward beginning 20 Feb. to within 14 km offshore Seahorse Key by 25 March. Locational data were limited during this period and subsequent locations were not received until early May. The turtle was 2 km southwest of Seahorse Key on 3 May, near the entrance to the Cedar Key ship channel, and was located

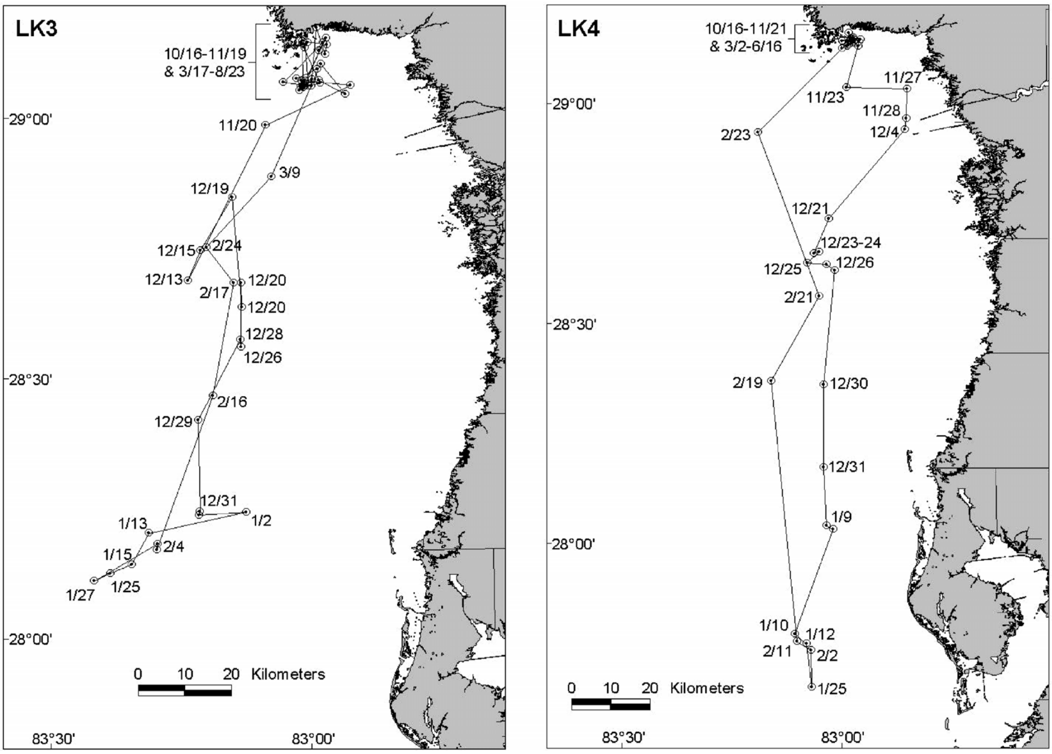

Fig. 3. Locations of Kemp's ridleys LK3 and LK4 along the west coast of Florida.

in this vicinity through 29 June when contact was lost. LK2 occupied a postmigration foraging range of 4.9 km^2.

Kemp's ridley No. 3: LK3 was captured at Corrigan Reef on 16 Oct., was located near the reef on 28 Oct., and moved approximately 6 km to the south-southwest by 12 Nov. The turtle moved southwestward through Nov. (Fig. 3), pausing approximately 45–55 km offshore Homosassa and Chassahowitzka bays on 13–28 Dec., and continuing south to 36 km offshore Anclote Keys by 31 Dec. LK3 moved gradually offshore through Dec. and southernmost migration was 56 km offshore Anclote Keys on 27 Jan. The turtle moved inshore in early Feb., returned to the area off Homosassa and Chassahowitzka bays from mid- to late Feb., and then progressed northward through 17 March to Cedar Keys. LK3 was located approximately 4 km southeast of Snake Key on 8–13 April, in an area corresponding to a series of deep channels bisecting shallow shoals (Fig. 1). The turtle alternated between Corrigan Reef (20 April, 21–25 May, and 13–20 June) and the area off Snake Key (22–24 April and 3–4 June), and then was located in the vicinity of the shoals from 15 July to 23 Aug. when contact was lost. LK3 occupied a postmigration foraging range of 48.0 km^2.

Kemp's ridley No. 4: LK4 was captured at Corrigan Reef on 16 Oct. and was located in the vicinity through 21 Nov. The turtle moved rapidly southeastward through the end of Nov. and paused at the outer channels of the Cross Florida Barge Canal and the Crystal River Power Plant from 28 Nov. to 4 Dec. (Fig. 3). LK4 continued southward to approximately 35–40 km offshore Chassahowitzka Bay and was located in this area 23–26 Dec. The turtle continued rapidly southward from late Dec. through early Jan. Movement slowed approximately 30 km offshore Johns Pass, the entrance to Boca Ciega Bay, on 10–12 Jan. Southernmost progression was 33 km offshore St. Petersburg Beach on 25 Jan., and LK4 returned to the area offshore Johns Pass on 2–11 Feb. The turtle began moving rapidly northward in mid-Feb. and returned to Corrigan Reef by 2 March. LK4 was located in the vicinity of the reef through 16 June when contact was lost, and occupied a postmigration foraging range of 3.8 km^2.

Kemp's ridley No. 5: LK5 was captured at Corrigan Reef on 17 Oct., but moved rapidly

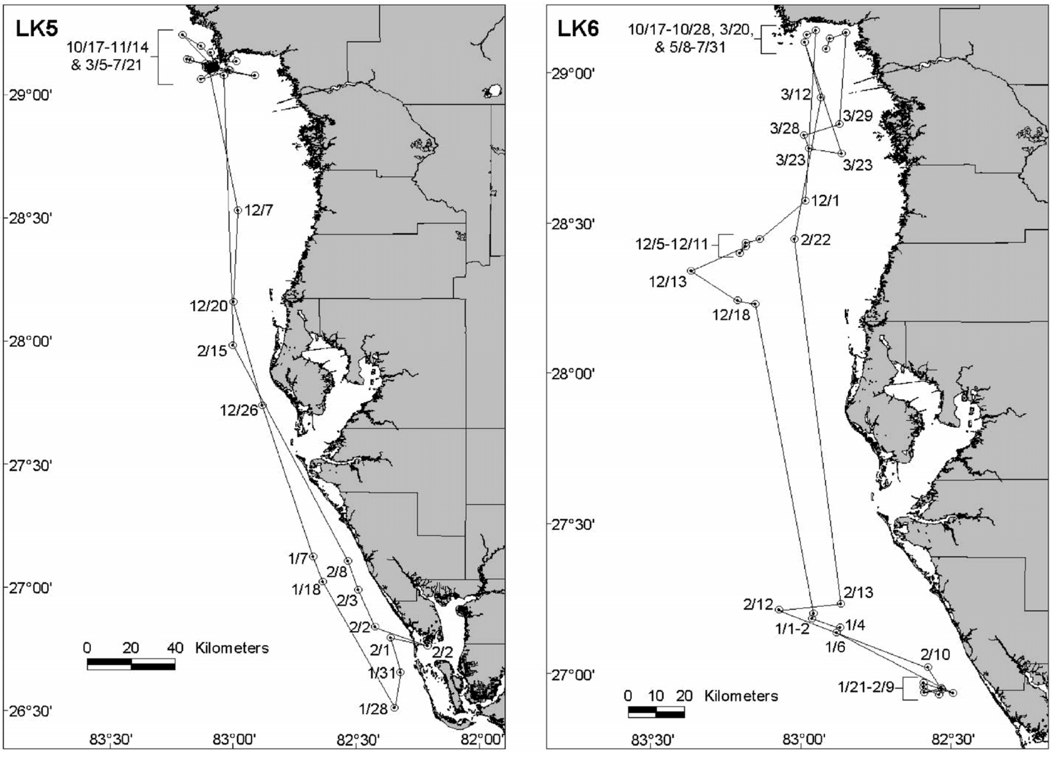

Fig. 4. Locations of Kemp's ridleys LK5 and LK6 along the west coast of Florida.

to the west and northwest to an area off Suwannee Reefs through 20 Oct. The turtle moved southward to a shoal area between North Key and Seahorse Key by 8 Nov. (Fig. 4) and was located in this locality through 14 Nov. LK5 moved 65 km to the south-southeast by 7 Dec. and was located 30 km offshore Weekiwachee River. The turtle continued southward through Dec., slowed progression 20 km offshore Venice Inlet on 7–18 Jan., and reached southernmost migration 15 km offshore Captiva Island on 28 Jan. LK5 moved northward to within 10–15 km offshore Gasparilla Island, and possibly into Charlotte Harbor on 2 Feb., before progressing northward to within 8 km of Venice Inlet on 3–8 Feb. The turtle continued rapidly northward to 17 km offshore Clearwater Pass on 15 Feb. The next location was received on 5 March, when LK5 had returned to Cedar Keys and was approximately 2 km south of Snake Key. The turtle then was located in the vicinity of North and Seahorse keys (Fig. 1), particularly in an area between these two islands, from 26 March until contact was lost after 21 July. LK5 occupied a postmigration foraging range of 8.1 km^2.

Kemp's ridley No. 6: LK6 was captured at Corrigan Reef on 17 Oct. and was subsequently located near the reef on 28 Oct. The turtle moved 61 km to the south by 1 Dec., paused in an area approximately 40 km northwest of Anclote Keys 5–11 Dec. (Fig. 4), and then continued slowly southward to within 30 km offshore Anclote Keys on 18 Dec. LK6 was subsequently located 115 km to the south on 1 Jan. and moved southeastward from 45 km offshore Siesta and Casey keys to within 12 km of Manasota Key by 21 Jan. The turtle was located 15–20 km offshore Manasota Key through 9 Feb. with southernmost progression on 31 Jan. LK6 began movement northward on 10 Feb. and was approximately 40 km offshore Siesta Key on 12–13 Feb. The turtle had moved 135 km to the north by 22 Feb. to 30 km north-northwest of Anclote Keys and continued northward to the offshore entrance to the power plant and barge canal by 12 March. LK6 appeared to have been located near the shoals off Snake Key on 20 March, but moved rapidly south to an area approximately 20 km offshore Homosassa Bay on 23–29 March. The turtle was located inside Waccasassa Reefs on 8 May and was located in the vicinity of these reefs on 27 May and 31 July. There were insufficient location data to calculate a postmigration foraging range for LK6.

SST and depth used by Kemp's ridleys.—Despite individual variability, Kemp's ridley turtles followed a similar pattern with regard to SSTs and water depths used during their respective tracking periods (Fig. 5). SSTs were greater than 20 C and depths were less than 3 m in Oct. when turtles were located in the Cedar Keys area. Mean SST used by turtles during the first 2 weeks of Nov. (23.6 ± 1.9 C; range: 21–27 C) was significantly greater ($\chi^2 = 17.2$, $P < 0.0001$) than that of the last 2 weeks (17.1 ± 1.5 C; range: 15–20 C). Most turtles began using deeper waters as they left the study area in late Nov. (Fig. 5). SSTs continued to decrease (mean = 15.4 ± 1.8 C; range: 12–19 C) and depths continued to increase (mean = 12.2 ± 4.1 m; range: 5–19 m) as turtles migrated southward through Dec. Minimum SSTs of 12–14 C were recorded in early Jan., and the mean SST used by turtles in the first 2 weeks of Jan. (14.0 ± 1.6 C; range: 12–17 C) was significantly lower ($\chi^2 = 13.5$, $P = 0.0002$) than that used in the last 2 weeks (16.6 ± 1.4 C; range: 14–19 C). Maximum depths of 16–27 m were recorded in Jan., but LK6 was the exception by moving to deeper water (31 m; Fig. 5) in early Feb. to an area previously occupied in early Jan. (Fig. 4). Turtles began using shallower depths in Feb. (mean = 14.9 ± 5.1 m; range: 2–31 m) as they began migrating northward. Depths used by turtles decreased significantly ($\chi^2 = 33.4$, $P < 0.0001$) in March (mean = 3.9 ± 4.6 m; range: 0.1–19 m) as they began returning to the Cedar Keys area. Mean SST used by turtles in Feb. (17.6 ± 1.7 C; range: 14–22 C) did not differ significantly ($\chi^2 = 0.03$, $P = 0.87$) from that used in March (17.7 ± 1.4 C; range: 16–22 C), but mean SST used in April (21.8 ± 1.6 C; range: 19–24 C) was significantly greater ($\chi^2 = 31.3$, $P < 0.0001$) than that of March. Mean SST used by turtles continued to increase in May (26.0 ± 2.1 C; range: 21–28 C) and June–Aug. (28.8 ± 1.2 C; range: 26–31 C), and depths were typically less than 3 m for the remainder of their respective tracking periods.

Variability in the depths used by individual turtles was related to the distances traveled southward and offshore. LK5 used the shallowest maximum depth and migrated the farthest south and the least distance offshore (Table 1; Fig. 4). LK3 migrated the least distance south and the farthest offshore (Table 1; Fig. 3), but LK6 used the deepest maximum depth and migrated the second farthest south and offshore (Table 1; Fig. 4). SSCL was not significantly correlated with maximum depth used by turtles ($r = 0.80$, $P = 0.055$); however, LK5 used relatively shallow depths for its size (Table 1; Fig. 5) and removing LK5 resulted in a significant correlation between SSCL and maximum depth used by remaining turtles ($r = 0.92$, $P = 0.027$).

Seasonal surfacing patterns.—Although the transmitters were not configured to record surface and submergence data, a pattern in the monthly proportions of location classes was observed that might suggest a seasonal change in surfacing behavior (Fig. 6). High proportions (75–77%) of locations requiring two uplinks with the satellite (LC B) and low proportions (7–9%) of locations requiring four or more uplinks (LC 0, 1, 2, 3) were obtained in Oct. and Nov., suggesting turtles were spending limited amounts of time at the surface. In Dec. and Jan., there was a pronounced increase in the proportions (40–45%) of locations requiring four or more uplinks. This indicates an increase in the number of messages received by the satellites, which may be indicative of turtles spending more time at the surface. The proportion of locations requiring 4 or more uplinks slowly declined in Feb. (27%) and March (13%), and remained low (<9%) through Aug. The monthly proportions for LC A were consistently low (9–18%) over the course of the study. There was a significant positive correlation ($r = 0.82$, $P = 0.002$) between monthly mean SST at turtle locations and proportions for LC B locations and a significant negative correlation ($r = 0.80$, $P = 0.003$) between mean SST and proportions for locations requiring four or more uplinks.

Discussion

Rather than exhibiting winter dormancy in the Cedar Keys, immature Kemp's ridleys in our study migrated southward and overwintered in offshore waters along the west-central and southwest coasts of Florida. The turtles followed similar temporal patterns in their seasonal movements despite individual differences in the extent of their migrations. Initial movements were similar, with turtles leaving the Cedar Keys area in Nov. when winter cold fronts decreased the water temperature to below 18 C. All turtles traveled southward in Dec., but some moved to deeper waters offshore of the west-central coast and others continued to shallower coastal waters off southwestern Florida. Despite differences in latitudinal and offshore distribution, Kemp's ridleys reached their southernmost migration by the end of Jan. and began moving northward to shallower waters in Feb. and March. All turtles eventually returned to the Cedar Keys area.

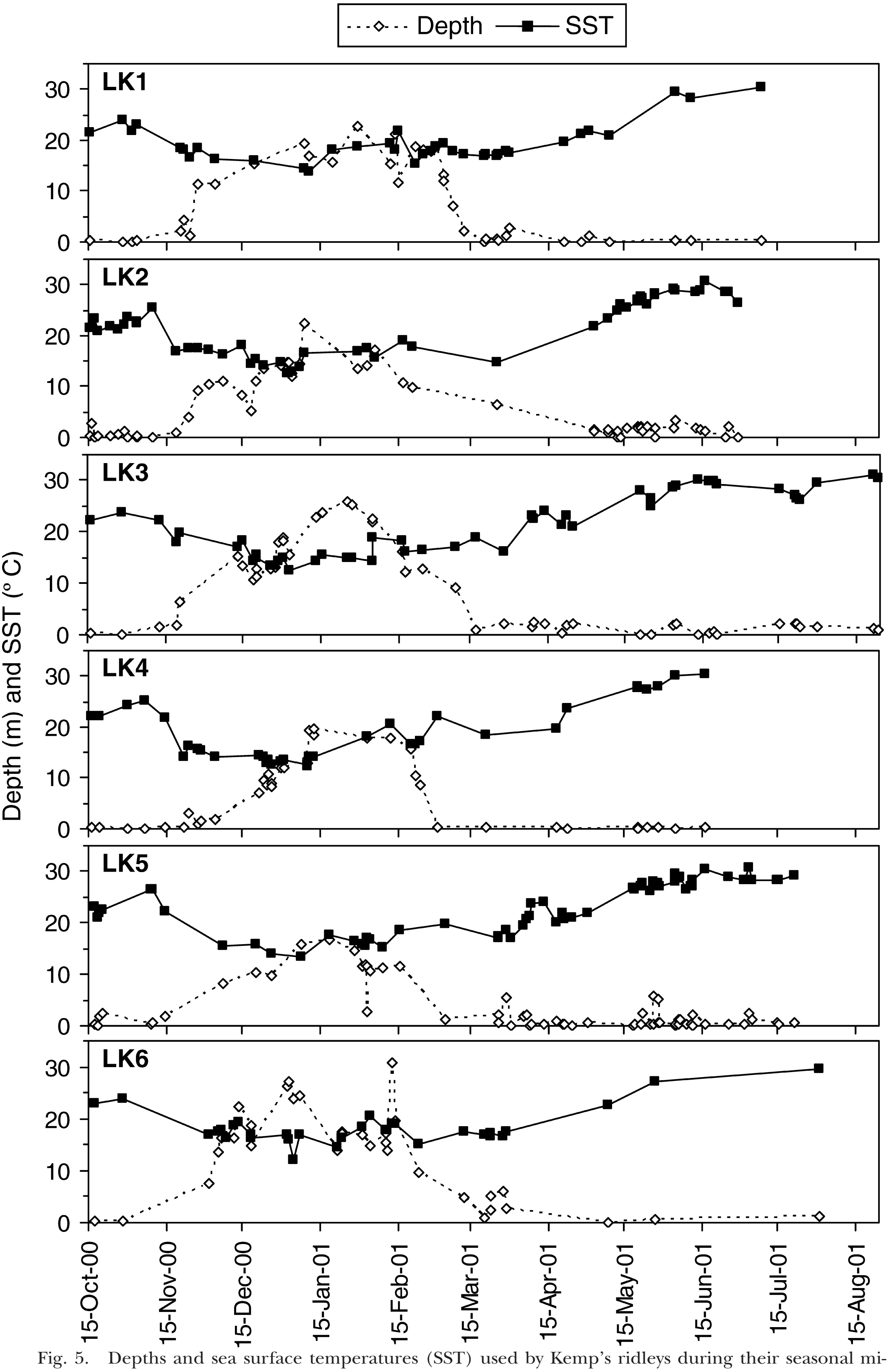

Fig. 5. Depths and sea surface temperatures (SST) used by Kemp's ridleys during their seasonal migrations in the eastern Gulf of Mexico.

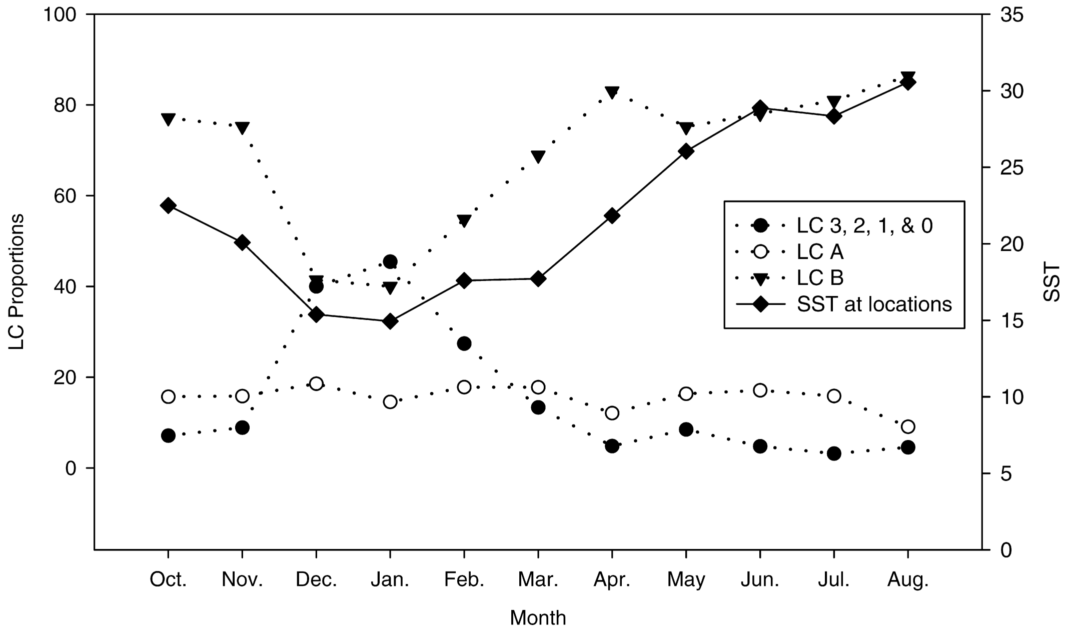

Fig. 6. Monthly proportions of location classes (LC) relative to mean monthly sea surface temperatures (SST) at the locations of telemetered Kemp's ridley turtles.

Kemp's ridleys exhibited strong fidelity to Cedar Keys foraging grounds in previous tagging and telemetry studies. Short-term recaptures at the site of initial capture suggested that turtles may remain in the area during their seasonal occurrence, whereas recaptures between seasons and multiannual recaptures suggested that turtles remigrate to capture sites and may do so for up to 4 yr (Schmid, 1998). Radio and sonic telemetry demonstrated that Kemp's ridleys occupied 5–30 km^2 foraging ranges in the vicinity of Corrigan Reef for up to 2–3 mo (Schmid et al., 2003). In our study, five turtles occupied relatively confined areas (4–48 km^2) in Cedar Keys through Aug., and three of these returned to their initial capture location. This latter observation provides evidence that Kemp's ridley turtles return to previously used foraging habitat, and the former suggests turtles may re-establish foraging range areas between seasons. Furthermore, turtles may remain in these areas before departing the following Nov. Perhaps immature turtles continue this pattern of seasonal migrations to and from Cedar Keys foraging grounds for a number of years until maturing and moving to adult foraging areas.

Kemp's ridleys along the U.S. Atlantic seaboard exhibited similar seasonal migrations. Turtles departed from New England waters in Oct. and Nov. and continued their migration southward off the coasts of Virginia and North Carolina through Nov. (Morreale and Standora, 1998, 2005). A subadult turtle (<60 cm SCL; Renaud, 1995) and an adult-size turtle (60.7 cm; Gitschlag, 1996) traveled southward from the coastal waters of Georgia and northern Florida in Oct. and Nov., remained in coastal waters south of Cape Canaveral from Dec. through Feb., moved northward in March and April, and resided off the South Carolina coast through July. The total distance these turtles migrated was 500–600 km. By comparison, Kemp's ridleys migrating along the west coast of Florida traveled shorter distances (<300 km) and their overwintering period appears to be of shorter duration. These slight differences in migratory behavior are probably because of the different water temperature regimes on the Atlantic and Gulf coasts of the southeastern United States.

Marine turtles are ectothermic and respond to changes in water temperature by moving to more favorable thermal environments. Gitschlag (1996) reported a thermal preference of 18 C or greater during winter migrations of Kemp's ridleys along the U.S. Atlantic coast. He also suggested that a rapid decline in water temperature stimulated winter migration southward and that the critical temperature range for the migratory response may vary with latitude (cooler in the north and warmer in the south). Moon et al. (1997) observed that Kemp's ridleys raised in captivity displayed a "hyperactive response" (continuous movement of the foreflippers) when exposed to water temperatures of 20–15 C, and this behavior may be indicative of a migratory response. Kemp's ridley turtles in Long Island Sound exhibited nondirected movements suggestive of foraging behavior from July to Sept. when water temperatures were >15 C (Morreale and Standora, 1998). More directed movements were observed in Sept. and Oct. when water temperatures were <15 C, and these eastward movements corresponded to departure from coastal estuaries. Kemp's ridleys in western Florida initiated southerly migrations after significant decrease in SST during late Nov., and the response occurred when mean SST used by turtles reached 17 C. Additionally, the onset of northward migration corresponded to a significant increase in SST during late Jan. when the mean SST used by turtles reached 17 C. As suggested by Gitschlag (1996), the migratory response corresponded to significant shifts in water temperature and the temperature triggering migration was slightly higher than that reported in New England waters.

Captive Kemp's ridleys stopped feeding when water temperatures fell below 15 C (Moon et al., 1997) and became cold-stunned (immobilized and floating at the surface) at 10–13 C (Schwartz, 1978). Epperly et al. (1995) reported sightings of turtles offshore North Carolina with SST estimates as low as 8 C, but indicated that most occurred in waters ≥11 C. SST estimates as low as 12 C were recorded in Jan. for Kemp's ridleys off western Florida. The low SST values reported from each of these studies are within the range at which cold-stunning occurs, but turtles did not appear to be exhibiting this response. The mean SST for all Kemp's ridley locations off western Florida in Jan. was 15 C, which is in agreement with the mean SST of 16 C recorded for loggerhead turtles off North Carolina (Coles and Musick, 2000). Although SST is a useful tool for investigating water temperatures used by marine animals, caution must be exercised when reporting absolute values given the potential for error with the estimates. Atmospheric water vapor is one of the major sources of error in the SST estimate (Tanahashi et al., 2000), and cloud cover can obscure the sea surface or artificially lower the values in the satellite image (Coles and Musick, 2000). Thin cirrus clouds and sea fog are particularly difficult to detect. Satellites with AVHRR sensors measure the temperature of the top few micrometers of water and, as such, SST estimates can be affected by extremely fast changes in air temperature. Rapidly declining air temperature and cirrus clouds after the passage of winter cold fronts may result in lowered SST estimates reported during winter months. Satellite transmitters with temperature sensors may provide more accurate measure of a turtle's ambient environment than estimates from remote sensing.

Cooler water temperatures would decrease the metabolic rate of an ectotherm, and, as a consequence, marine turtles would be expected to respond via their respiratory activities. Captive-raised Kemp's ridleys changed their breathing pattern from single breaths to multiple breaths, thus spending more time at the surface, and also exhibited longer surface durations when water temperature was reduced to <20 C (Moon et al., 1997). The submergence durations of a turtle migrating along the U.S. Atlantic coast were significantly longer in winter than in spring (Gitschlag, 1996). A Kemp's ridley at Cedar Keys moved southward to relatively deeper waters after the passage of a Nov. cold front, and subsequently exhibited fewer surfacings with longer submergence durations (Schmid et al., 2002). The mean surface duration for Kemp's ridleys migrating down the east coast of Florida in fall (approximately 90 sec; Gitschlag, 1996) was four times longer than that of turtles inhabiting the Cedar Keys during the summer (18.5 sec; Schmid et al., 2002). Although surfacing and submergence data were not recorded in our study, an increase in the proportion of higher-quality location classes suggests that migrating Kemp's ridleys are spending more time at the surface during winter months. Seasonal influences on activities and respiratory behavior have important implications for estimating in-water abundance via aerial and shipboard surveys, which rely on sightings of turtles at or near the surface (Shoop and Kenney, 1992; Mullin and Hoggard, 2000; Griffin and Griffin, 2003).

Kemp's ridley turtles have been described as a coastal species with movements and migrations typically within 15 km of shore and water depths <18 m (Renaud, 1995). Gitschlag (1996) tracked two immature Kemp's ridleys off the southeastern U.S. coast and these turtles were located 6–29 km offshore and in water depths <24 m. An adult-size turtle was tracked up to 80 km off Cape Canaveral but overwintered within 20–40 km of the east-central coast of Florida. In our study, immature Kemp's ridleys migrating along the west coast of Florida traveled up to 13–56 km offshore to maximum depths of 15–31 m. Aerial surveys off southwest Florida have documented the occurrence of Kemp's ridleys up to 127 km offshore and at depths up to 50 m (Fritts et al., 1983). Satellite telemetry has recently demonstrated that postnesting females migrate from Texas to southwest Florida (D. Shaver, pers. comm.), so the occurrence of Kemp's ridleys farther offshore may represent observations of adult turtles. Ogren (1989) proposed size-specific depth use based on the diving constraints of smaller Kemp's ridleys, and the results of our study suggest that larger turtles used deeper depths. However, larger turtles can also use shallower depths as exhibited by LK5. The aggregation at Cedar Keys is skewed toward larger size classes of immature turtles (Schmid, 1998), which is another confounding factor when investigating depth use by size. The seasonal migrations of smaller Kemp's ridleys, such as those occurring in the Big Bend region of northwestern Florida (Schmid and Barichivich, 2004), should be investigated to determine possible size-specific differences in depth use and migration patterns.

Although studies have documented the seasonal migrations of Kemp's ridleys, there is no information available on their winter habitat use. Turtles inhabiting the nearshore waters of Cedar Keys exhibited a preference for live bottom (i.e., sessile invertebrates attached to hard bottom substrate) and this may be the habitat used during winter migrations (Schmid, 2000; Schmid et al., 2003). Despite differences in scale and resolution, a cursory examination of the Southeast Area Monitoring and Assessment Program (1991) data for southeastern Florida and the movements of a telemetered Kemp's ridley (Gitschlag 1996) indicated that the turtle was in the vicinity of hard bottom areas south of Cape Canaveral from Dec. through March. Live bottom communities off the east coast of Florida are more abundant south of Cape Canaveral, particularly upon knolls, ridges, and rocky outcrops (Jaap and Hallock, 1990). The West Florida Shelf has scattered, low-relief outcrops of chert and limestone that support a variety of macrobenthic fauna (Brooks, 1973; Collard and D'Asaro, 1973). A Kemp's ridley turtle was identified in a photographic survey of benthic communities in the shelf waters of southwestern Florida (Rosman et al., 1987); however, the time of year and the exact location of the sighting were not identified. Benthic surveys are needed off the west-central and southwest coast of Florida to determine if the winter localities frequented by telemetered turtles correspond to areas of live bottom habitat.

The detailed description of Kemp's ridley locations provided in our study will allow managers and conservationists to identify existing and potential impacts in migratory routes along the west coast of Florida. For example, these migration paths coincide with fishing efforts for pink shrimp (*Penaeus duorarum* Burkenroad) along the west coast of Florida (Osborn et al., 1969) and shrimp trawling has been identified as the primary source of human-induced mortality for marine turtles (National Research Council, 1990). LeBuff (1990) indicated that Kemp's ridleys were captured by shrimp trawlers fishing off southwestern Florida, and the size class for Kemp's ridleys stranding along the coast (40–60 cm; Teas, 1993) corresponds to the size classes of turtles in Cedar Keys (Schmid, 1998). However, current regulations requiring the mandatory use of turtle-excluder devices in shrimp trawls should lessen or negate incidental captures in this fishery. Nonetheless, potential anthropogenic impacts include interactions with other commercial or recreational fisheries, entrainment in power plant intake canals, ocean dumping of pollutants, and petroleum exploration and extraction in the waters off western Florida. Protection of migrating Kemp's ridleys and their winter habitats in the eastern Gulf of Mexico is essential to maintaining the viability of this endangered species.

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