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Author(s): C. Robert Shoop, Carol A. Ruckdeschel, Nancy B. Thompson
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SEA TURTLES IN THE SOUTHEAST UNITED STATES: NESTING ACTIVITY AS DERIVED FROM AERIAL AND GROUND SURVEYS, 1982

C. ROBERT SHOOP, CAROL A. RUCKDESCHEL, AND NANCY B. THOMPSON

ABSTRACT: Aerial surveys over the entire United States shoreline from Cape Hatteras, North Carolina, to the Texas–Mexico border by a single observer team during the spring and summer of 1982 showed greatest sea turtle nesting in Florida (accounting for more than 85%) followed by South Carolina, Georgia, North Carolina, and Alabama, respectively. Almost all nesting activity was by loggerheads (*Caretta caretta*). Ground surveys in Georgia and Florida provided correction factors for aerial counts of fresh nesting crawls (tracks). No fresh nesting crawls in areas of ground survey were missed by the aerial team.

Possible reasons for present nesting distributions include egg predation by native and feral domestic animals, habitat destruction by introduced animals, natural and human-induced changes in beach areas, and temperature regimes of past decades and centuries. Nesting sea turtles may shift to other beaches if natal beaches are no longer available; consequently, beaches presently supporting small nesting populations may become more important to the species in the future.

Key words: Sea turtles; *Caretta*; *Chelonia*; United States nesting distributions; Aerial surveys

ALTHOUGH there are numerous accounts of sea turtle nesting activity for segments of the Atlantic and Gulf coasts of the United States (e.g., Davis and Whiting, 1977; LeBuff and Hagan, 1978; Richardson et al., 1980), and estimates of total nesting activity for the south Atlantic shore (Powers, 1981) and the Atlantic and Gulf coasts (Hopkins and Richardson, 1984), comprehensive surveys of the entire area are lacking. We report herein the results of aerial surveys of sea turtle nesting from Cape Hatteras, North Carolina, to the Rio Grande River, Texas, and ground surveys in Georgia and Florida during 1982. This study represents part of an ongoing National Marine Fisheries Service program to assess the status of sea turtle stocks along the shores of the United States.

The most recent summary of nesting activity for the United States coast was presented in the Recovery Plan for Marine Turtles (Hopkins and Richardson, 1984), and it was based on available literature, internal governmental agency reports, and personal communications. The nesting data utilized in that report varied greatly in quality and precision and were primarily counts or estimates for restricted segments of the coast obtained over various periods in the past. Nevertheless, it is the best assemblage of data on nesting by sea turtles in the United States to date.

The study presented here includes data derived from comprehensive aerial surveys flown over large areas in a short period of time by the same personnel. Such surveys allow comparisons from one area to another, and with certain corrections, the data provide estimates of numbers of turtles nesting in the surveyed areas. We report the distributions of nesting tracks, estimates of numbers and types of nesting turtles, and possible reasons for the distributions observed. Aspects relating to the special problems of interpreting aerial survey data, establishing adjustment values, additional 1982 aerial surveys, and detailed methods of survey are presented elsewhere (Shoop et al., unpublished data).

The purpose of this study was to establish an index of marine turtle nesting activity for the southeastern United States for 1982 through aerial and ground surveys, thereby providing the basis for evaluating possible trends in nesting activity in the future. A method for establishing correction factors for aerial counts of sea turtle tracks (crawls) was needed, and concomitant ground surveys and repetitive aerial surveys were used to establish these factors. The sea turtles of the United States are all classified under the Endangered Species Act as threatened or endangered; hence, these baseline data provide the foundation for measurements of change and future management.

METHODS

The survey area, the shoreline from Cape Hatteras, North Carolina, to the Rio Grande River, Texas, was divided into variably sized, shore sections (map intervals) ranging from 0.2–29.9 km. These sections were marked on aeronautical charts. A list of shore sections and their lengths is available from the authors.

Three surveys, one each in May, June and July 1982, were flown as soon after the new moon as weather permitted to take advantage of the reduction of old turtle tracks by spring tides. The May survey included the area from Cape Hatteras to Key West; the June survey was from Cape Hatteras to Key Biscayne, Florida, around the Florida Everglades and along the Gulf Coast to Mexico. The July survey covered from Cape Hatteras to Key Biscayne. The Florida Keys were not surveyed in June and July because suitable and observable nesting habitat was lacking. Dates and areas covered are presented in Table 1.

TABLE 1.—Dates and areas of aerial surveys, 1982.

Date	Area
26 May	Cape Hatteras, NC–Fernandina Beach, FL
27 May	Fernandina Beach, FL–Key West, FL
23 June	Cape Hatteras, NC–Fernandina Beach, FL
24 June	Fernandina Beach, FL–Key Biscayne, FL; Homestead, FL via Cape Sable–Sannibel Island, FL
25 June	Sannibel Island, FL–Marsh Island, LA (except Seahorse Key, Tyndall AFB traffic area, and Pensacola NAS traffic area, FL)
26 June	Marsh Island, LA to U.S.–Mexico border
22 July	Cape Hatteras, NC–Fernandina Beach, FL
23 July	Fernandina Beach, Fl–Key Biscayne, FL

All surveys were flown at altitudes of 74–104 m, offshore above the surf line in a Cessna 182 high-wing aircraft at speeds of 115–120 knots except in areas of high nesting activity where speeds were reduced to between 70 and 80 knots. All flights were made with the right side of the aircraft shoreward. Normal protocol in observation was for the pilot to announce locations, the forward observer to call all observations, and the recorder to hand-record times, locations, and pertinent data. Surveys through rain were continued as long as tracks were adequately visible.

Whenever doubt about counts occurred because of high densities of crawls, the entire section was again surveyed. In areas of high nesting activity, communications were tape-recorded, and all tape recordings were later compared to written recordings. Any differences were resolved according to the real-time tape recordings.

Sea turtle tracks were recorded as fresh nesting crawls (FNC) or fresh false crawls (FFC). Fresh crawls were considered less than 24 h old. The criteria for a crawl to be called a nesting crawl were tracks leading to a disturbed site or tracks leading into vegetation. No attempt was made to judge whether a turtle actually prepared a nest or deposited eggs. Often the legs of a nesting track were of different length owing to tide changes between time of exit from and entry into the water. False crawls were assigned to tracks that simply wandered across sandy beaches or overwash areas without any "nesting type" disturbance, to "U-shaped" tracks below the high tide line, or to tracks of sea turtles encountering obviously unsuitable nesting sites (rock, sea wall or cliff) with lack of a "nesting site" disturbance. These criteria did not allow for subjective judgment of whether a turtle actually nested in a body pit or disturbed area since such a situation would be deemed a nesting crawl. This

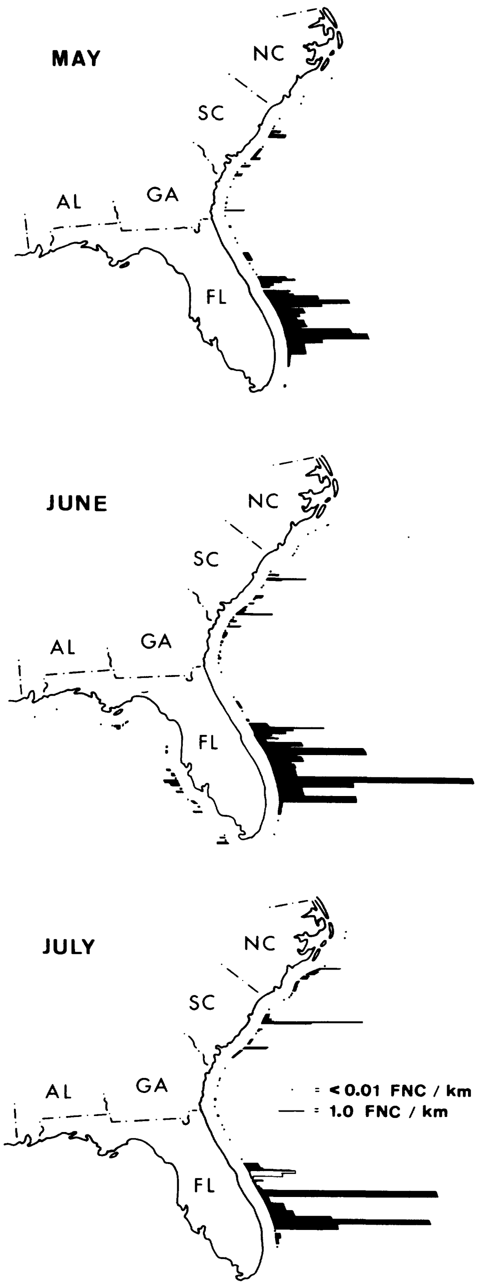

FIG. 1.—Maps of study area showing distribution of nesting on survey day in May, June, and July 1982. Data presented as number of estimated fresh nesting crawls (FNC) per kilometer. Open strip off Florida in July represents ground counts only.

procedure assured that the actual number of nesting crawls would always be over-counted and the number of false crawls under-counted by aerial survey when compared to ground survey data.

Crawls made by different species varied in flipper track pattern and size, with green turtles (*Chelonia mydas*) and leatherbacks (*Dermochelys coriacea*) having opposite flipper marks as contrasted to alternate track patterns of loggerheads (*Caretta caretta*) and hawksbills (*Eretmochelys imbricata*). Leatherback tracks are wider than those of green turtles (Pritchard, 1982), but hawksbills could not be differentiated from loggerheads by our methods. We assumed that hawksbill nesting would be negligible on any given day in the study area (Sternberg, 1981). Kemp's ridley turtle (*Lepidochelys kempi*) was anticipated only on the Gulf Coast, and its track would be narrower than the other species.

Ground survey data were provided for selected areas in Georgia and Florida. In Georgia, James Richardson coordinated ground survey information on Wassaw, Jekyll, Little Cumberland, and Cumberland islands (61.4 km of beach). In Florida, Llewellyn Ehrhart provided ground survey data for Brevard County beaches, about 113 km in length.

Ground survey data were needed to modify (adjust) aerial survey counts because age of crawls and actual deposition of eggs could not be absolutely determined from the air. Ground counts provided correction indices which we applied to the aerial counts to estimate the total number of FNC for that day. Correction indices varied for each survey because of different environmental conditions affecting the beaches (including prior winds, precipitation, tides), and possibly because of different viewing conditions.

RESULTS

Results of the survey flights of May, June and July 1982 are presented in Fig. 1. The May survey from Cape Hatteras to Key West showed greatest nesting activity in

TABLE 2.—Summary of fresh nesting crawls recorded by monthly aerial surveys and estimates of actual fresh nesting crawls by state and region, 1982.

Area	May			June			July		
	Air FNC	Adj. value	Est.	Air FNC	Adj. value	Est.	Air FNC	Adj. value	Est.
NC	3	0.60	1.8	12	0.47	5.6	34	0.80	27.2
SC	38	0.60	22.8	84	0.47	39.5	80	0.80	64.0
GA	17	0.60	10.2	36	0.47	16.9	10	0.80	8.0
FL east coast	466	0.89	414.7	989	0.63	623.1	1416	0.41	618.6†
Subtotal	524		449.5	1121		685.1	1540		717.8
FL west coast				97	0.63	61.1			
AL				2	0.63	1.3			
Subtotal				99		62.4			

† Thirty-eight FNC added from ground count in areas not aerially surveyed.

Florida (Table 2), but no turtle crawls were observed in the Florida Keys where the availability of nesting sites was extremely limited and tracks were unlikely to be observed from the air because of vegetation. All tracks were identified as loggerhead crawls in both aerial and ground surveys.

In June, when the coast was surveyed from Cape Hatteras around the tip of Florida, and along the entire Gulf of Mexico shore to the Rio Grande River, Florida again had the highest nesting activity (Table 2). There was an increase over May counts in North and South Carolina. Again all tracks were identified by the aerial surveys as being made by loggerheads, but ground surveys in Florida identified one green turtle fresh nesting crawl. In the Florida ground truth area where both aerial and ground surveys were completed, the fraction of nesting allotted to green turtles was only 0.0055, an almost insignificant amount. The westernmost nesting crawl on the Gulf Coast was on the Alabama shore. Two false crawls were observed on the Chandeleur Islands, Louisiana. No crawls were observed in Texas although visibility was excellent.

During the July survey from Cape Hatteras to Key Biscayne, the same pattern of nesting activity was obvious (Table 2), with only loggerhead crawls identified in aerial and ground surveys. As in the May and June aerial surveys, this portion of the study area was surveyed in two days.

The total number of estimated fresh nesting crawls (aerial counts × adjustment values) from Cape Hatteras, North Carolina, to Key Biscayne, Florida, was 450 in May, 685 in June, and 718 in July. That for the entire Gulf Coast was 62 in June. The percentages of total estimated fresh nesting crawls by state and percentages of shoreline are presented in Table 3.

Two areas on the Florida east coast,

TABLE 3.—Percentages of total estimated fresh nesting crawls by state for each monthly survey with percentages of shoreline, Cape Hatteras, North Carolina to Key Biscayne, Florida, and data for Florida divided to show areas of relatively high and low nesting activity.

State	Survey			% of shoreline
	May	June	July	
NC	0.4	0.8	3.8	25.3
SC	5.1	5.8	8.9	20.8
GA	2.3	2.5	1.1	11.5
FL	92.2	91.0	86.2*	42.3
FL				
Florida north border to New Smyrna Beach, and Boca Raton to Key Biscayne	3.6	1.8	0.8	19.3
New Smyrna Beach to Boca Raton	88.7	89.1	85.4*	23.1

* Percentage includes ground data for intervals lacking aerial surveys.

from Melbourne Beach South to Sebastian Inlet and from Hobe Sound National Wildlife Refuge to Lake Worth Inlet, had the highest frequency of fresh nesting crawls for all three monthly surveys. On the day of the July survey, there were an estimated 5.45 fresh nesting crawls per kilometer in those two shore segments which comprise about 4.5% of the East Coast shoreline from Cape Hatteras to Key Biscayne. This area supported about 45% of the estimated loggerhead nesting for the July survey. A larger continuous area from New Smyrna Beach south to Boca Raton beach, which includes the two shore segments mentioned above, contained the majority of nesting crawls on the East Coast of the United States for that day. On survey days, this stretch of Florida beach (319.6 km) supported from 89% of the estimated nesting on the East Coast in May to 85% in July, on 23% of the total shore (Table 3).

Only one other area on the East Coast consistently produced relatively high nesting crawl counts: Cape Island in Cape Romain National Wildlife Refuge. Although providing only 3% of the South Carolina shoreline, this 8.6 km, eroding beach (Mathews et al., 1980) held from 21% (May) to 55% (July) of the total nesting crawls estimated for South Carolina on the survey days. On the July survey, Cape Island had an estimated frequency of 4.09 fresh nesting crawls per kilometer.

On the Gulf Coast, most nesting activity was recorded from Port Boca Grande to Sarasota and from St. George Island to Cape San Blas, Florida. As on the Atlantic Coast, Florida beaches supported most nesting activity on the Gulf Coast (Fig. 1).

Concomitant ground survey data from Georgia and Florida for the monthly surveys showed that in all areas, the number of fresh nesting crawls recorded by aerial survey was higher than recorded on the ground, and fresh false crawls were proportionally higher in ground counts as expected.

Fresh false crawls were mapped by aerial and ground surveys with the assumption they would be needed for evaluating the aerial counts of fresh nesting crawls. This proved incorrect. The only value of ground survey mapping fresh false crawls, many of which came under the aerial survey criteria of fresh nesting crawls, was that it provided an explanation of aerial survey misinterpretations, but fresh false crawls did not influence the adjustment values for the estimated numbers of actual fresh nesting crawls.

In July, the rather wide differences in aerial and ground counts of fresh nesting crawls (596 and 242, respectively) within the Florida ground survey area varied in part because of unusually low tides (due to offshore winds) when spring tides were expected, differences in rainfall over the ground survey area just prior to the survey flight, and extremely high densities of old and new crawls resulting in a complex spectrum of tracks often superimposed upon each other. Unexpected problems with a missile launch at Cape Canaveral reduced aerial coverage in the July survey, but ground surveys were completed and provide a count for those intervals not surveyed from the air.

Because, (1) the monthly aerial surveys observed every fresh nesting crawl in the area of ground surveys in Georgia, (2) many old nesting crawls were called fresh from the air, and (3) our criteria for determining a fresh nesting crawl from the air assured some fresh false crawls would be included in that number, the number of fresh nesting crawls recorded by the monthly aerial surveys always matched or exceeded the number of actual fresh nesting crawls reported by the ground surveys. This greatly reduced the potential bias for estimating the number of actual fresh nesting crawls for the entire survey. By concentrating on only fresh nesting crawls and the percentages of those correctly identified to arrive at an estimate of total numbers of actual nests, we eliminated concern for details of track misidentifications. Whenever the aerial count of fresh nesting crawls is consistently the same or greater than the ground count, whether the individually mapped tracks correspond or not, the adjustment values will be the same for mapped and unmapped data, obviating the need for mapped comparisons.

Discussion

The numerous published records of the relative amount of sea turtle nesting on the United States shore have suffered from lack of comparative data. Previous reports on the importance of some nesting areas must be revised, because local conditions have changed, populations have decreased, or previous estimates lacked sufficient data. For instance, Hopkins and Richardson (1984) listed Georgia and North Carolina as "major" nesting areas, but these states accounted for only a very small proportion of the nesting crawls that we recorded. Richardson et al. (1980) indicated Raccoon Key, Georgia, as a high density nesting beach in 1977, but by 1982 a mud flat had developed on the ocean side of the island thereby making beach access difficult for female turtles and drastically reducing nesting activity. Regardless of differences in the amount of relative nesting activity from previous reports, the geographical nesting range reported in our study conforms to past ideas of the distribution of nesting sea turtles on the United States coast. The lack of nesting on much of the western Gulf Coast supports the finding of Hildebrand (1982) who could document only two loggerhead nests in Texas and one in Louisiana.

Our data indicate nesting activity only for the day of survey. Extrapolations to predict number of nests per season would be based on a knowledge of individual nesting frequency, duration of individual female nesting seasons, and daily variability of nesting on the various beaches. We assume that nesting beach fidelity is high (Richardson et al., 1978), but the critical observations to define variability of fidelity to a beach and duration of individual nesting seasons have not been made. The loggerhead turtles tagged on Georgia islands might well be used to define such critical information, but adjacent and distant beaches would need to be monitored for the occurrence of Georgia-tagged turtles. Even on regularly patrolled beaches in Georgia, many animals are missed during night patrols. For instance, turtles accounting for 67 of 226 crawls (or 29.6%) in the five-mile study area on Cumberland Island, Georgia, in 1983 were missed by the tagging team (A. Kontos, personal communication).

Assuming fidelity to any one nesting beach or series of adjacent beaches, a possible factor in the present day loggerhead nesting distributions on the Atlantic and Gulf coasts is the past and present occurrence of domestic and feral animals. The first swine to reach the United States were landed on the Gulf Coast in 1539 by DeSoto (Towne and Wentworth, 1950) and along with horses and cattle were common stock of the colonizing Spanish in 1565 (Lowery, 1911). Over 400 yr of predation on sea turtle eggs by feral swine may now be reflected in the seemingly erratic turtle nesting distributions. We have observed heavy swine predation on sea turtle eggs only in areas with dense swine populations, therefore predation pressure from swine may vary from year to year, allowing some nesting success, albeit low.

Other domestic animals such as cattle, horses, and certain imported cervids have also possibly contributed to nesting distributions. Their grazing and trampling the stabilizing dune vegetation frees the sand, allowing wind and water erosion and sometimes complete loss of nesting habitat. In the 1920's, the beach on the southern half of Cumberland Island, which suffered much damage by grazing animals, lacked dunes and simply eroded into forest, presenting a steep vertical face to the surf and preventing successful sea turtle nesting. The present nesting activity is concentrated on the north end of the island, probably as a result of the dune and beach destruction decades ago on the south end. Similar situations could have occurred elsewhere and contributed to present nesting distribution patterns. When combined with normal beach dynamics, continual natural modifications, nest predation by native animals, and human generated perturbations, the effects of domestic and feral animals on present day nesting patterns may be profound. If sea turtles do return to their natal beaches to nest as suggested by data of Smith et al. (1978), current centers of sea turtle nesting activity reflect the coastal conditions of decades and centuries past.

Considering the variety of natural and human-induced changes in shoreline qualities and the relatively rapid nature of these possible changes, nesting sea turtles must be able to shift to other beaches more readily than is generally supposed. Elimination or control of feral animals on many barrier islands may allow an increased production of hatchlings and ultimately an increase in numbers of nesting females. Management decisions must acknowledge the probability that nesting patterns are labile and that beaches presently not heavily utilized by nesting sea turtles may become important nesting beaches in the future.

Another factor impinging on nesting distributions is the temperature range of nesting habitats. The impact that temperature influenced sex determination and embryo survival have on the size of resulting female nesting populations has not been assessed, but is also of potential significance in determining present distributions and local stock sizes. Temperature regimes of nesting beaches may account for the present day nesting distributions by governing the number of females produced in each area, but data are lacking. Mrosovsky et al. (1984) attempted to address this question, but their conclusions were unsupported and obfuscated because they pooled data from different years (= different climate regimes), had too few samples, combined natural and hatchery nest data, and recorded no temperatures. They did show that some natural nests in South Carolina produce both males and females.

Subject to the many factors mentioned above, we expect that nesting patterns will change over time. Our surveys provide a comprehensive perspective of sea turtle nesting distributions on the Atlantic and Gulf coasts of the United States and provide a base for comparisons in the future. Subsequent aerial nesting surveys could improve precision by providing data on daily and seasonal variability of nesting crawl numbers and observer differences. When coupled with a more complete knowledge of sea turtle nesting biology, estimates of nesting derived from aerial surveys will have greater precision.

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CRS and CAR: *Department of Zoology, University of Rhode Island, Kingston, RI 02881, USA;* NBT: *National Marine Fisheries Service, Southeast Fisheries Center, 75 Virginia Beach Drive, Miami, FL 33149, USA*

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A NEW SPECIES OF SOUTH AMERICAN WATER SNAKE (GENUS *LIOPHIS*) FROM SOUTHEASTERN BRAZIL

JAMES R. DIXON AND ROBERT A. THOMAS

ABSTRACT: A new species of colubrid snake, *Liophis atraventer*, is described from the rainforests of southeastern Brazil.

Key words: Colubridae; *Liophis atraventer*; Neotropics; South America; Systematics

FOR the past eight years, we have been involved in studies of several South American genera of snakes e.g., *Liophis, Philodryas, Tropidodryas, Platinion, Pseudables, Umbravaga, Xenodon,* and *Lystrophis*. In 1977, Paulo E. Vanzolini informed us that he found what he thought to be a new species of *Liophis* (described herein) at the biological station of Boracéia, São Paulo, Brazil. Both of us examined the material at that time, but being unsure of the status of all 110 or more taxa in the genus at that time, we did not describe the Boracéia specimens.

At the present time, the genus *Liophis* contains five Caribbean species (seven if one includes *L. melanotus* and *L. reginae*, which reach Trinidad and Tobago), and 26 mainland Latin American species (Dixon 1980, 1981, 1983*a,b,c,d*; Dixon and Thomas, 1982). We are aware of two additional new species (unpublished data), increasing the total number of species of *Liophis* to 34.

The new species described herein is related to a species complex of *Liophis* containing four unicolored species (*L. guentheri, L. jaegeri, L. typhlus, L. viridis*) and two blotched species (*L. almadensis, L. poecilogyrus*). See Table 1 for