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I. NESTING AND MIGRATION OF THE ATLANTIC LOGGERHEAD TURTLE[1]

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SYNOPSIS: Tagging evidence shows that female Atlantic loggerhead sea turtles may travel as much as 1000 shoreline miles away from the nesting beach in 10 months.

The nesting procedure of the Atlantic loggerhead is described and illustrated. The loggerhead sometimes nests singly, but more often in aggregations on restricted stretches of beach. Loggerheads mate in the water just off the nesting beach, though whether before or after nesting, or both, is still unknown. No correlation exists between the size of the turtle and the time of laying or the number of eggs laid.

The principal nesting range of the subspecies is the mainland coast of North America from about Cape Lookout, North Carolina, to Mexico; emergences have been recorded occasionally on certain northern Caribbean islands and as far south as Costa Rica. The Atlantic and Pacific subspecies of the loggerhead cannot be separated by their marginal laminae.

Despite the large size of the Atlantic loggerhead turtle, *Caretta caretta caretta* (Linnaeus), and its common occurrence along heavily populated shores, its movements and certain details of its nesting habits are still poorly known. This is an account of recent observations on the species' nesting and of results of tagging operations on the coasts of Georgia and Florida.

MIGRATION

Long Range Travel

It has long been suspected that the stray loggerheads found occasionally in European waters were individuals from American waters, where the nearest upstream nesting grounds lie (in relation to the Gulf Stream). Although it may never be possible to prove the Amer-

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ican origin of the European loggerheads, and while it may eventually be shown that they derive from downstream rookeries, on the Mediterranean coasts for example, we now at least have a tag return which proves an impressive distance traveled between known points during a known period of time.

The turtle recovered was a female with a carapace length (measured as described by Carr and Caldwell, 1956: 4) of 35 inches, tagged by Caldwell and Thomas R. Hellier, Jr. while nesting at Hutchinson's Island, opposite Jensen Beach, Martin County, Florida, on 27 May 1957. It was recaptured by a shrimp trawler off the mouth of the Mississippi river, probably near Pass-a-Loutre, about 24 or 25 March 1958. It was thus at liberty for about 302 days and was retaken about 1000 shoreline miles from the place of tagging. To reach the point of recapture by the shortest route without crossing the open Gulf, this turtle had to travel southward around the tip of Florida and then northward and westward into the north-central Gulf of Mexico. The length of time between tagging and recapture suggests the animal may have taken a more circuitous inshore route. Although the trip might seem to imply continuous travel against the Gulf Stream, an examination of major seasonal current systems in the Gulf of Mexico (as given by Leipper, 1954: 121-122) shows that the turtle might actually have been helped by currents. Caldwell, Berry, Carr, and Ragotzkie (1959 herein) show that loggerheads nest more than once a season. Although by no means proved, it also seems likely that they remain in the general vicinity of the rookery area throughout the nesting season, or until late summer. If this turtle left the Jensen Beach area in late August, it could have passed around the southern tip of Florida free of opposition by the Gulf Stream simply by staying close inshore until it reached Florida Bay. From the southeastern Gulf of Mexico the currents flowing generally northward and westward along the eastern Gulf coast in the late winter and early spring could have helped it reach the Mississippi by March. This is one of the longest journeys ever proved for any reptile, being rivalled only by trips made by female green turtles tagged in Costa Rica (Carr and Ogren, Ms.).

The only other tagged loggerhead recovered an appreciable distance from where it was marked made a much shorter journey in much less time. Caldwell, Carr, and Hellier (1956b) reported an individual tagged when nesting at Fort Pierce, (Hutchinson's Island, Florida), and recaptured 3 weeks later by a shrimp trawler off Daytona Beach, Florida, some 130 shoreline miles northward. The re-

covery indicates that mature loggerheads may travel considerable distances in a fairly short period of time. This turtle, like the other, could have been helped by ocean currents, in this case the northward-flowing Gulf Stream.

Movements of the Hatchling

One of the major problems in the study of sea-turtle life histories is the question of where the post-hatchlings spend the first months after they leave the nest. It has been pointed out (Deraniyagala, 1939; Carr, 1952) that small specimens of the Atlantic ridley sea turtle, *Lepidochelys kempi* (Garman), occasionally reach points far distant (England, for example) from their probable natal beaches. Such occurrences suggest a passive migration in the form of a post-hatchling drifting in the major ocean currents, the Gulf Stream in particular. The ridley is the only species in which this conjecture has been supported by concrete evidence, and even this is meager.

We know of no previous records of sea turtle hatchlings taken away from a nesting beach or at sea. Two recent captures are thus of interest. William W. Anderson took a young loggerhead in a dipnet at the surface in 200-fathom water at 25° 10′ N., 80° 02′ W., about 15 miles southeast of Key Largo, Florida, 26 July 1957. This animal, now in the collection of the Bureau of Commercial Fisheries Biological Laboratory at Brunswick, Georgia, still has its egg tooth and umbilical scar and measures 64 mm. in carapace length. Two other hatchlings, one badly macerated, the other in fair condition, were taken from the belly of a 7-foot female white-tipped sharp (*Carcharhinus longimanus*) caught at 30° 50′ N., 78° 45′ W., 135 miles due east of Cumberland Island, Georgia, 22 August 1957. These specimens, now in the University of Florida Collections, show juvenile characters and measure 47.5 mm. in carapace length. They were sent us by Dr. Richard Backus of the Woods Hole Oceanographic Institution, who has been consistently generous with sea turtle data gathered incidental to his oceanographic studies.

Comparison with captive loggerheads of known age (cf. Caldwell, Carr, and Hellier, 1956b: 297) suggests the first specimen was about 11 weeks old, the second two about 12 to 13 days old when eaten. Whether these turtles were lost waifs drifting to oblivion in the open sea, or whether they occur in these localities regularly after leaving the nesting beaches is still uncertain. If they occur in these waters regularly, it is strange that the biologists who have spent hundreds of hours observing and dipnetting there have reported no others.

Mating and the Nesting Process

Colonial Nesting

Although the loggerhead nests on the beaches of all the coastal South Atlantic and Gulf states roughly from Cape Lookout, North Carolina, to Texas, it apparently concentrates its nesting activity in restricted areas which may conveniently be termed "rookeries." Similar rookeries are known for other species of sea turtles, particularly the green turtle. We have found three such nesting concentrations of loggerheads on the Atlantic coast of the United States; one is Hutchinson's Island, Florida; another is Jekyll Island and the adjacent Little Cumberland Island near Brunswick, Georgia; the third is Cape Romain, South Carolina, fortunately located within a United States Fish and Wildlife Service wildlife refuge. Aerial reconnaissance of the coast of Florida north of Matanzas Inlet, of the entire coast of Georgia and of most of that of South Carolina, has shown the apparent concentration of nesting activity on Jekyll and Little Cumberland Islands and at Cape Romain to be real. While a few nests were observed scattered along the entire stretch of coast, each flight showed the places mentioned to be far more heavily used than any other area. Surveys of the south Florida coast indicate that Hutchinson's Island is similarly important as a rookery.

In addition to the concentration of tracks seen from blimps on Jekyll and Little Cumberland Islands, evidence that these islands near Brunswick are used as a rookery has been supplied by William W. Anderson. While conducting shrimp studies for the Fish and Wildlife Service with the Brunswick shrimp fishery off the Georgia islands, particularly from 1930 to 1938, he found loggerheads quite rare in the area each year during the fall, winter, and early spring. In late spring as the summer nesting season approached, the turtles appeared in large numbers in these particular waters, and were seen nowhere else in abundance, neither off neighboring islands nor in the sounds and passes. The turtles off Brunswick were at times plentiful enough to be a nuisance to the shrimp fishermen whose trawls they damaged. As shrimping continued after the turtle nesting season, it provided a good sampling opportunity, which indicated a real influx of mature-sized loggerheads from outside the rookery area during the nesting season. Brunswick shrimp fishermen working today say that although the total loggerhead population has been reduced, this same seasonality in abundance occurs.

Mating

In both the Atlantic and Pacific green turtles mating occurs mainly off the nesting beach (Harrisson, 1954; Carr and Giovannoli, 1957: 30.). William W. Anderson's observations suggest that similar behavior is characteristic of loggerheads. He had excellent opportunities between 1930 and 1938 to observe the turtles clearly from his slow-moving trawler, and states that he often saw loggerheads mating in the water just off the Georgia beaches, particularly near the passes between the sea islands where the beaches are located. Not being aware at the time of the scarcity of such data, Anderson kept no records of dates, but he clearly recalls that this mating behavior took place each year he worked in the area, and always during the nesting season of the loggerhead. His observations agree with those of others that mating loggerheads tend to ignore a nearby boat. He never saw mating turtles in threes—a female with two attending males—as has been reported for the green turtle by Carr (1956) and by Carr and Giovannoli (1957: 31); although elsewhere we have been told of observations of such trios of loggerheads (see also Caldwell, 1959, herein).

Anderson noted that the influx of turtles to the waters off the nesting beaches began as much as a month before actual nesting. This fact may bear on the problem of whether mating occurs just before laying or afterwards, a detail not yet determined for any species of American sea turtle (Carr and Giovannoli, 1957: 31; Carr and Ogren, Ms).

Nest Building and Oviposition

Although the nesting of the Atlantic loggerhead frequently has been described in popular articles, the only accounts in zoological literature that recount the process in detail are the composite descriptions of Mast (1911) and Carr (1952: 390). After observing nesting loggerheads for several seasons we find that these accounts require modification. Accordingly we present the following description of the nesting of the Atlantic loggerhead and the accompanying series of photographs showing some of the more important details. Both the notes and pictures are composites, because it is difficult to find turtles just emerging from the sea and to follow and photograph the entire procedure of a single individual. However, the behavior was so similar in all localities and at all times of the nesting season that the account given here is believed to be representative of the Atlantic loggerhead on the coasts of Florida and Georgia.

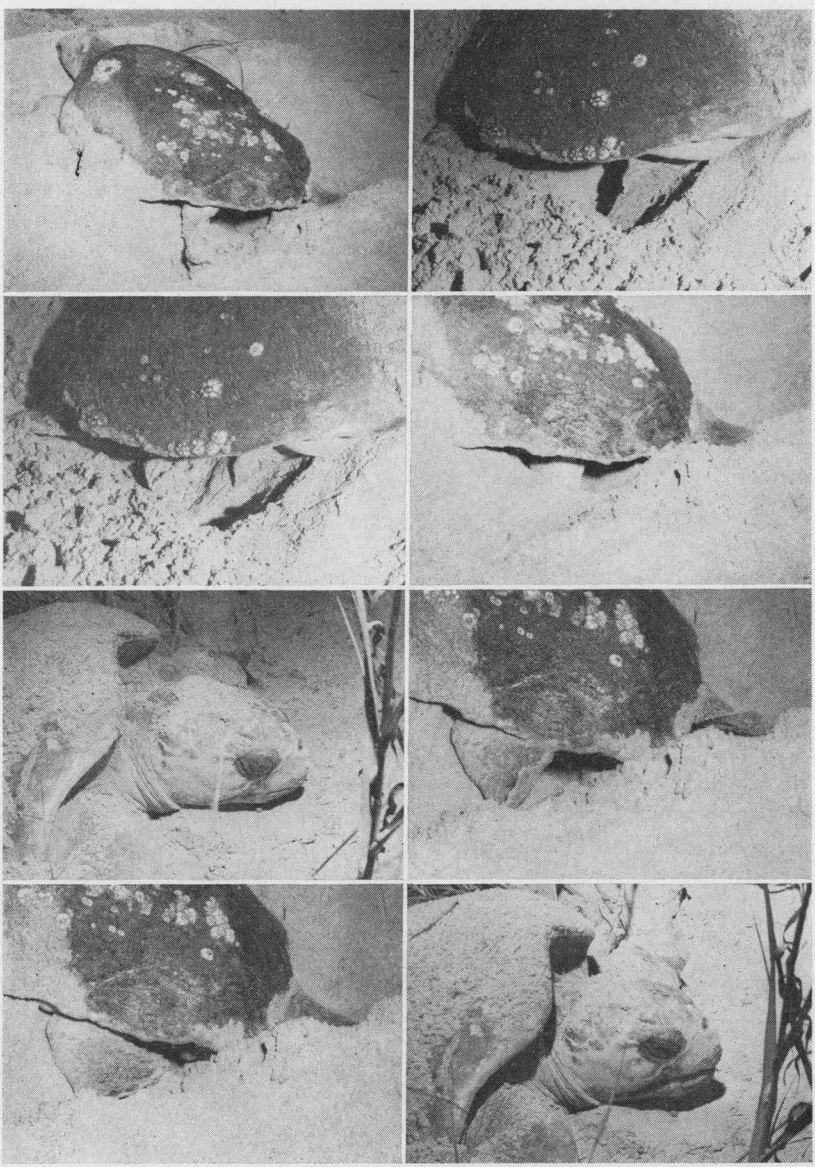

Figure 1.—Nesting Atlantic loggerhead, showing large excavation made preliminary to actual digging of nest (see text).
Figure 2.—Flipper inserted into growing nest cavity.
Figure 3.—Flipper lifting sand out of nest cavity.
Figure 4.—Left flipper digging, right flipper flat on sand.
Figure 5.—Head down and neck arched prior to laying. Note open eye and tears.
Figure 6.—Hind flippers raised before group of eggs is extruded.
Figure 7.—Hind flippers lie flat on surface of sand during intervals between extrusions of eggs.
Figure 8.—Head raised between extrusions of eggs. Note tears and open eye.

On first leaving the water, and even until she has started to dig, the turtle is easily disturbed. She reacts strongly to a light thrown directly upon her. Contrary to Carr's account (1952: 390), after the site for the evening's activity is selected all turtles observed dug a preliminary excavation of varying extent. The female uses all four flippers in this process until she has lowered herself several inches below the surface of the sand (Figure 1). Digging of the actual nest follows almost immediately, for which only the hind flippers working alternately are used. With its outer edge downward, one flipper is inserted into the sand or into the growing hole (Figure 2). It is then cupped, and the outer edge is rotated inwardly. A small amount of sand is now scooped up (Figure 3), lifted to the top of the hole, and deftly laid to one side. Meanwhile the opposing flipper remains flat, "palm" down on the sand near the edge of the hole (Figure 4). The turtle now shifts her body so this other flipper comes into position over the hole. Just before she inserts it into the hole to dig, she flicks it out laterally and upward to brush the loose sand, deposited when this flipper last excavated, away from the edge of the hole. This technique differs only in minor points from that described for the green turtle by Carr and Giovannoli (1957: 25).

The digging process is then repeated as the turtle shifts to bring the first flipper into play again. Almost as soon as the nest is finished the flippers are laid straight back or pointed slightly outward, "palms" down (Figure 7), and the cloacal "ovipositer" is inserted. During the digging process the head has been held flat on the sand and the eyes kept open, although blinking occasionally. The eyes secrete copiously (Figures 5 and 8) during the digging and laying. Just before each group of eggs falls (in groups of one, two, or three) the neck is arched with the head still down (Figure 5), and the hind flippers are raised slightly (Figure 6). As each group of eggs falls, the neck is lowered to the position held during digging and the flippers come down and lie flat again between extrusions (Figure 7). During this interval, the head may be raised slightly (Figure 8) and the turtle may snort or sigh by expelling air from her nostrils or mouth.

Carr and Giovannoli (1957: 25) stated that the loggerhead will press its vertically oriented back flippers against the upper part of the wall of the nest cavity "as if to keep sand from falling in," and Carr (1952: 11) illustrates the maneuver in *Lepidochelys*. Despite numerous attempts, we never succeeded in bringing about this behavior in a laying Atlantic loggerhead. Several times we dug part of the wall of the nest away to reveal the eggs for photography, and never did the

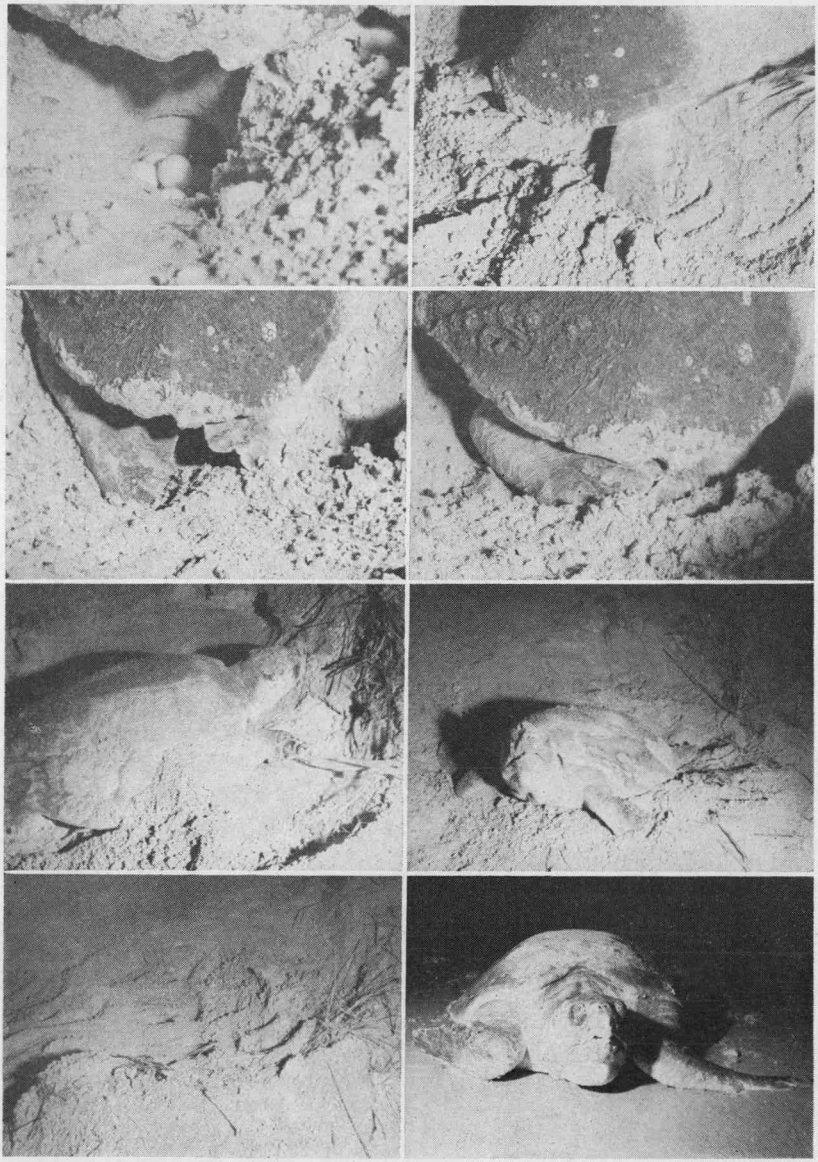

Figure 9.—Nearly cylindrical nest cavity almost filled with eggs.
Figure 10.—Rear flipper dragging sand to fill nest and cover eggs.
Figure 11.—Hind flippers packing sand in filled nest.
Figure 12.—Hind flippers packing sand in filled nest.
Figure 13.—All flippers sweeping sand to conceal the site.
Figure 14.—Turtle about to leave the nest. Note lifted head, open eye, and prominent hyoid apparatus.
Figure 15.—Nest site after departure of turtle. Trail leads off to left.
Figure 16.—Turtle crawling to the surf after nesting. Note position of head.

turtle attempt to shore up the crumbling nest. Once when we moved the posterior end of the turtle away from the nest opening she continued to lay on the surface of the sand beside it. When replaced over the hole, she continued to lay as if nothing had happened.

When the nest is filled with eggs (Figure 9), covering begins almost immediately. Sand is drawn in by the hind flippers, usually working alternately, sometimes together. The outer edge of the flipper is used, the limb reaching well forward and out from the body to drag sand back to the hole (Figure 10). As filling proceeds, the front flippers join in sweeping sand backward to replenish that pushed into the nest cavity by the hind legs and, like the hind flippers, the front ones are used either alternately or together. When the hole is full of loose sand, the hind flippers press it down firmly (Figures 11 and 12). During the filling and packing process the head and fore part of the body are sometimes raised as if to shift weight to the hind flippers and help them exert more force. Perhaps this shifting and raising of the body to increase pressure at the hind flippers accounts for the impression that the site is "pounded." Although it was expressly watched for, no turtle was seen to pack or pound the nest with her plastron, as reported by Carr (1952: 391). As the filling reaches completion, the front flippers aided somewhat by the hind ones begin to fling sand backward. This increased exertion pivots the turtle on the pedestal of sand her digging leaves under her plastron.

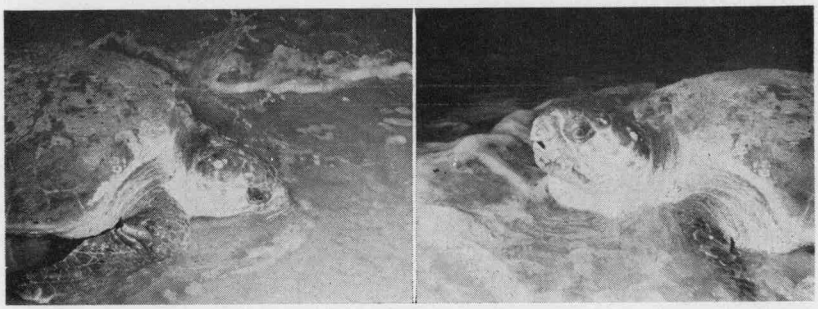

Figure 17.—Arrival at water, snout lowered into surf.
Figure 18.—Head raised before turtle proceeds through surf.

After completing the nest the turtle rests for a short period, and she also rests between the several subsequent outbursts of sand-flinging before moving away from the site. The flinging of sand—presumably aimed at concealing the site, and certainly effective—often enlarges the preliminary excavation (Figure 13). Just as the turtle moves

away from the site she raises her head high with the eyes still open, as they have been throughout the nesting process (Figure 14), and the hyoid apparatus becomes quite prominent as it moves in and out. When she leaves the nest, the site (Figure 15) is so camouflaged that the eggs are hard to find without the aid of a probing rod.

The return trip to the surf is usually made quickly and purposefully. Although the head is slightly raised while the turtle drags herself along (Figure 16), on reaching the water she drops her head into it (Figure 17). After a moment she raises it again (Figure 18) before moving rapidly out of sight into the sea.

Agent Robert Kilby of the Georgia Game and Fish Commission has told us of turtles completing the digging activity, laying a few eggs, beginning to cover these, and then laying the rest of the complement before finally covering the nest.

One collaborator let a turtle complete her nest, and when he turned her to be tagged she layed another mature egg. We allowed one turtle to finish her nest and then killed her to examine her for internal eggs. Though she had laid 90 eggs in a normal fashion and covered her nest, she still retained two mature eggs in the lower oviduct.

While the size of each egg in a clutch remains fairly constant, unlike those of the leatherback, *Dermochelys coriacea coriacea* (Linnaeus), (see Caldwell, Carr and Hellier, 1956a: 282; Caldwell, 1959; Carr and Ogren, in press) we twice found a single tiny egg in a normal clutch at the Jekyll Island rookery. These small eggs, somewhat oblong and measuring about 20 mm. in their greatest dimension, were fully shelled but contained no yolk and only a small amount of albumen. It was not ascertained when they were deposited.

Time of Emergence

Nesting loggerheads usually come out of the sea shortly after dark, and most of their nesting activities take place during the first 4 or 5 hours after dusk (see Caldwell, 1959, herein). As no case of a loggerhead nesting after daylight has been reported in the literature, the following observations are of interest.

On 13 July 1958 Caldwell, in company with Frederick H. Berry and Robert A. Ragotzkie, made a low-altitude aerial survey of the sea beaches from Cape Romain, South Carolina, to Brunswick, Georgia. At 0905 hours they observed a large loggerhead just returning to the water after apparently having nested on a beach just north of the inlet to Charleston Harbor, S. C. Official sunrise was 0500 hours and,

as the day was clear, it was full daylight by 0545. The tide had just turned to flood and, as the tracks leading out of the water extended nearly to the water's edge, the turtle could not have been on the beach more than the normal hour or so. From the air it appeared that this turtle had started and completed a normal nesting during full daylight.

During mid-July 1954 Agent Robert S. Pfister of the Florida State Board of Conservation made a similar observation on Hutchinson's Island about 1 mile south of the Fort Pierce Inlet where he had noted little preivous nesting. A rather small turtle appeared on the beach before sunrise when the dawn was just light enough so that "one would not need lights to drive a car on the highway." The turtle made a leisurely but direct trip to a spot above the high tide mark, dug its nest, laid, covered the eggs, and returned to the water. By then the sun had been above the horizon for a full hour.

A third instance, by coincidence also on 13 July 1958, was reported by Agent Kilby, who saw a turtle on Jekyll Island covering her eggs well after daylight. He believed that she must have left the water at about 0530 to 0600 hours, well after daylight. Kilby found another loggerhead after daylight on the south end of Jekyll Island which he thinks was lost on the broad sand flat, for her back trail was unusually long and meandering.

Agents Pfister and Kilby guard two of the three greatest loggerhead nesting grounds on the entire Atlantic coast of North America. They patrol the beaches in their charge with motor vehicles nearly every night throughout the turtle nesting season, from just after dark to past dawn. They undoubtedly see most of the turtles that emerge on their beaches, possibly more than are seen by any other men alive.

Size of Nesting Females

Carapace lengths to the nearest one-fourth inch were recorded for 110 turtles nesting on Jekyll Island from 29 May through 31 July 1958. The mean length was 37¾ inches, with a range of 31¼ to 45¼ inches. An analysis showed no correlation between the size of the turtles (either mean or range) and the dates they nested.

Size of Turtle in Relation to Number of Eggs Laid

The number of eggs in 25 clutches was compared with the size of the turtles laying them. Analysis of these variables showed no correlation.

Nesting Range

Each year since Carr's first visit to Tortuguero, Costa Rica, in 1953 the local turtle-turners there have reported the emergence of a loggerhead or two among the green turtles, Atlantic hawksbills (*Eretomochelys imbricata imbricata* (Linnaeus)), and Atlantic leatherbacks (*Dermochelys coriacea coriacea* (Linnaeus)). Though hundreds of turtles were examined there during the tagging program (Carr and Giovannoli, 1957; Carr and Ogren, in press; Carr and Ogren Ms.) no loggerhead was found until the summer of 1957, when early in the evening of 29 July a small (carapace length 34 inches) female came out on the beach and was turned by Durham Rankin, a creole in the employ of the project (Figure 19). The southernmost previous recorded emergence for the loggerhead was from the north coast of Cuba (Caldwell, Carr, and Hellier, 1956b: 296), though Lewis (1940: 62) noted that the species is reported to nest on the Cayman Islands.

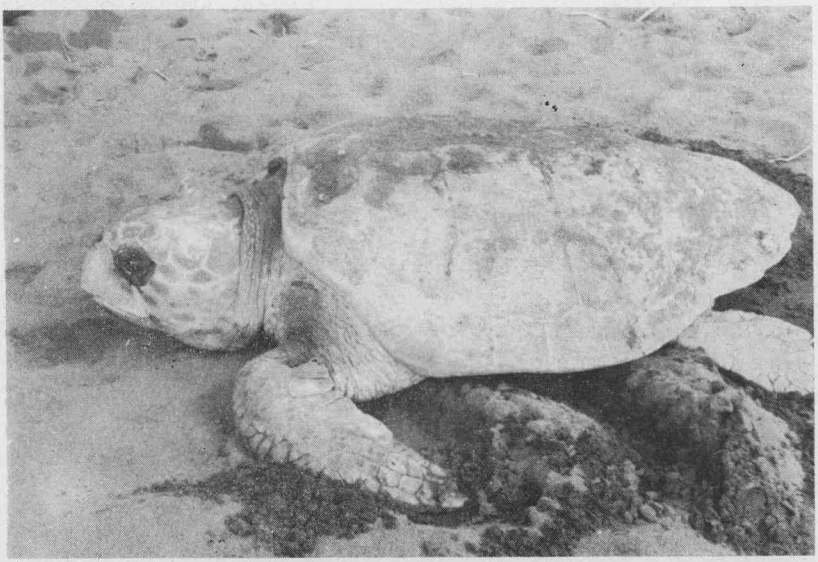

Figure 19.—Female loggerhead photographed on the beach at Tortuguero, Costa Rica; the first emergence recorded for the species in American waters south of Cuba.

The case presents an extreme example of the tendency, observable in other species of marine turtles and mentioned earlier in this paper as characteristic of loggerheads of the Atlantic coast, to nest either in aggregations or as isolated individuals. Breeding aggregations of animals usually develop integrating bonds that place the

aberrant individual with an urge toward solitary breeding at a selective disadvantage. The chances for consummation of any reproductive venture apart from the group effort, especially when a long migration to the nesting grounds is involved, would appear slight. With the sea turtles we can at present only point out the phenomenon and hope that with better understanding of the organization of the breeding group an explanation will eventually emerge.

Variation in Marginal Laminae

One character used to distinguish between the Atlantic and Pacific subspecies of the loggerhead has been the number of marginal laminae; the Atlantic form is supposed usually to have 12 on each side and the Pacific race 13 (see, for example, Carr, 1952: 382). Counts of the marginal laminae in two small groups of hatchlings, each group from a single clutch of eggs and both from Jekyll Island, show this character to be invalid. In one group 8 specimens had a 13-13 count, 4 a 12-12. The other group had 5 with a 13-13 count, 6 with 12-12, and one with 13 on the left and 12 on the right.

Acknowledgments

We wish to thank the many people who furthered our studies with information, physical aid, and encouragement. Some of these are: Frederick H. Berry, Harvey R. Bullis, Jr., Rolland C. Byrd, Mr. and Mrs. Henri Casanova, Hugh M. Fields, David Gould, Evelyn Hellier, Thomas R. Hellier, Jr., James R. Pearce, Teodoro Quiros C., and Robert A. Ragotzkie.

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We are especially indebted to Agents Robert Kilby and Robert S. Pfister, respectively of the Georgia Game and Fish Commission and the Florida State Board of Conservation, for their untiring cooperation in the field. Officials of both these agencies were most helpful in granting us collecting and study permits. William W. Anderson generously furnished us with important unpublished notes on Georgia sea turtles; and to him, to Frederick H. Berry, and to Jack W. Gehringer we are indebted for critical reading of the manuscript.

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