Anim. Behav., 1976, **24**, 849–857

ORIENTATION AND BEHAVIOUR OF HATCHLING GREEN TURTLES (*CHELONIA MYDAS*) IN THE SEA

BY J. FRICK
P.O. Box 293, Lincoln, Massachusetts 01773

Abstract. To investigate the initial stage of the 'lost-year puzzle' of sea turtle ecology, both hatchlings from the natural nesting ground at Tortuguero, Costa Rica and hatchlings from Tortuguero eggs that had hatched in a beach on Bermuda were tracked individually after their departure from these beaches. Of the Bermuda beach most were tracked by swimmers equipped with face mask and flippers and followed by a boat. Tracking off Tortuguero was done by an observer in a following boat. The data showed that non-random departure courses were maintained even when the swimming hatchlings had moved over the horizon from all fixed objects on the shore. Observations were made on swimming and diving behaviour and on predator relationships of travelling turtles. The procedures described are useful research techniques and will be used for more extensive tracking in future seasons.

One of the important remaining gaps in the natural history of sea turtles is the so-called 'lost-year mystery', the lack of information on the range and habitat of the young of any species from the time they enter the sea until they reappear as yearlings. Insofar as there is any theory to explain the puzzle, it is that the time of early development is passed in drifting masses of sargassum weed (Carr 1966). Although a few hatchlings, all loggerheads (*Caretta caretta*), have actually been found off the Florida coast in sargassum weed (Caldwell 1968), the theory is still a long way from substantiation, and the means of testing it are few. The present paper presents information bearing on the above theory and other aspects of the behaviour of hatchlings during the first stage of their marine existence.

The cues that guide newly emerged hatchlings from the nest to the sea have been thoroughly characterized during the course of more than 50 years of investigation. However, this tropotactic orientation in response to brightness differences between the landward and seaward horizons is of no use to a turtle in the open ocean with no landward horizon in sight. Readers may gain access to the sea-finding literature via the following citations, but should keep in mind that this phase of the life cycles of sea turtles is distinct from and of limited relevance to the open-sea migration described in this paper (Parker 1922; Carr & Ogren 1960; Ehrenfeld 1968; Mrosovsky & Shettleworth 1968).

The well known swim-frenzy, in which confined hatchlings move constantly against the walls of a tank for days after they are taken from the nest, suggests that young sea turtles probably travel steadily for at least 24 hr after leaving the beach. It seems likely that if the initial course taken could be determined by tracking, this might provide clues to the ultimate destination of the young. The present paper presents data bearing on this problem.

Methods

Bermuda

The work in Bermuda was carried out in 1970 and 1971. The hatchlings used were allowed to move naturally to the sea after emerging from the sand in which the eggs were incubated. The hatchery was established on Nonsuch Island and Howard Bay as part of an effort to test the possibility of rehabilitating the green turtle populations of the islands. Dr H. C. Frick and the author with the collaboration of Professor Archie Carr and the Bermuda Department of Agriculture and Fisheries had developed this as a pilot reintroduction project. Each summer several hundred eggs were transported from Tortuguero to Bermuda where the young turtles hatched and were released in the sea.

Initial releases in 1968 suggested that the travel of the hatchlings after passing through the surf remains steady and oriented. Trial runs in 1970 showed that it was feasible for a good swimmer to travel indefinitely behind a hatchling without either losing sight of it or permanently influencing its orientation or behaviour. In all tests, hatchlings were held from 2·7 to 25 hr in covered buckets lined with a piece of damp cloth or paper, until the trackers and boats were ready. Under natural conditions, hatchling green turtles usually emerge from the nest and go to sea at night, or just before dawn.

Visual tracking at this time would obviously be impossible, because the hatchlings tend to orient toward an extraneous source of light, and using a lantern or a flashlight would therefore be ruled out. Moreover, tracking at night would be dangerous for the swimmer since sharks are common inshore after dark. However, natural emergences of young turtles do occur in the daytime, and daytime observations are therefore regarded as a valid record of natural behaviour.

Hatchlings were released in groups on the beach and allowed to crawl to water without interference. Distances travelled on the shore were 6 m or more. The mean temperature of the Bermuda water for October is 22°C, which is about six degrees cooler than the waters off the ancestral nesting beach at Tortuguero during the hatching season there. This difference in temperature should influence the swimming speed of hatchlings. However, the average swimming rate of hatchlings off Bermuda unexpectedly was higher than at Tortuguero. As is discussed later, this difference can be accounted for by strong longshore current off Tortuguero, against which the turtles are headed, and the presence of frigate-birds (*Frigata magnificens*) which cause the turtles to dive.

Once the young turtles had gone through the surf and had swum until they were clearly out of visual contact with each other, a hatchling was assigned to each of several trackers. The tracker, equipped with mask and flippers, followed his hatchling at a distance of 1·5 m to 3 m. At this distance, the swimming turtle was easily visible against the sky from depths of approximately one and a half metres. To determine whether the presence of a tracker influenced the continuity of direction of travel of the subject, test runs were made in which the swimmer changed positions from right to left, or moved up close behind or beside the hatchling. None of these manoeuvrings produced more than transitory changes of course. Although a turtle's swimming rate could be accelerated by the swimmer if he approached the turtle rapidly from behind, even when a tracker moved up closely and held a hand in front of the swimming hatchling, the interruption of locomotion was only momentary, and the turtle

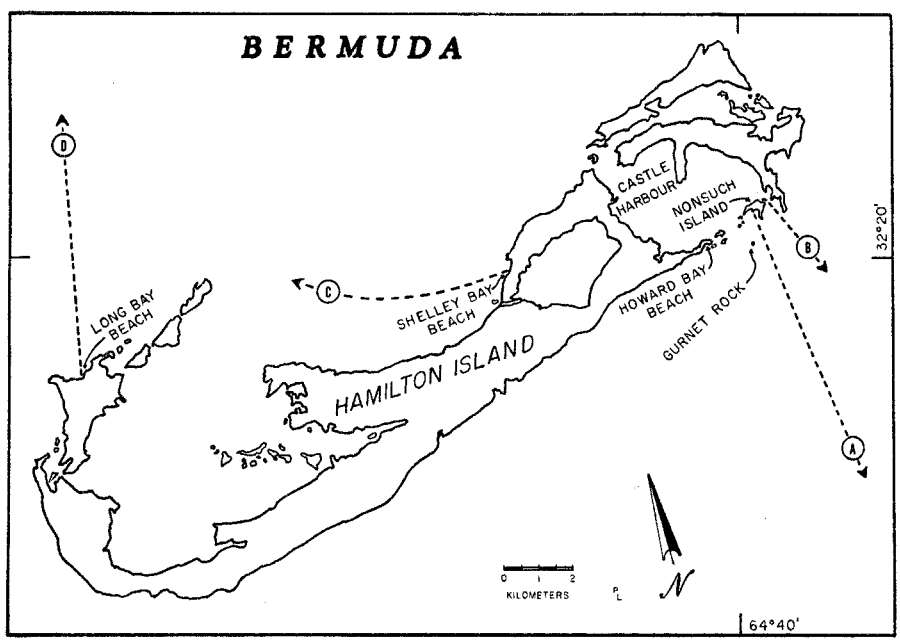

Fig. 1. Bermuda. The arrows show general directions taken by groups of hatchlings released in 1971 at four sites, as follows: A. Nonsuch South Beach; B. Nonsuch North Beach; C. Shelly Bay Beach; D. Long Bay Beach.

regularly resumed travel in the original direction. If the swimmer blocked the path of the turtle by swimming in front of it or to the side, it would increase its speed and make every effort to regain its original heading.

Boats followed close behind the trackers at all times. To learn whether the presence of a boat influenced locomotion and heading, the tolerance tests made by the trackers were repeated, with similar results. Even when a boat was stopped directly across the path of a swimming turtle, it merely dived, came up on the other side, and continued on the original course at the same steady pace.

The course of each turtle was plotted from line-of-sight fixes made from the boats on prominent objects on shore every 10 to 15 min. The shore was visible from the deck of the boat long after it had disappeared at turtle-eye level.

During the seasons of 1970 and 1971, turtles were released on five different beaches (Figs 1 to 6). Only two of these, Nonsuch South Beach and Howard Bay, are hatchery sites. Hatchlings released on the other three beaches were transported there by boat. Howard Bay (where only a single turtle was tracked in 1970), Nonsuch South Beach, Long Bay Beach and Shelly Bay Beach face the open ocean. The fourth, Nonsuch North Beach, is in a small channel between Castle Harbour and the ocean. Seventeen turtles were tracked by swimmers followed by boats for 1 to 4 hr. Nine were lost within the first hour.

Tortuguero

At the Tortuguero nesting ground three turtles were tracked just after being excavated from nests that were ready to emerge naturally on the shore. All hatchlings were released on wave-washed sand 3 m or less from the sea because the black volcanic sand of the beach was extremely hot from the sun. Because of the shark menace there, tracking was done from a boat in which a person operating a small outboard motor in the stern was guided in the path of the hatchling by an observer in the bow. Successive bearings of the positions of the boat were recorded at approximately 5 to 10-min intervals by the observer with alidades separated by a 750-m base line on shore. The approximate

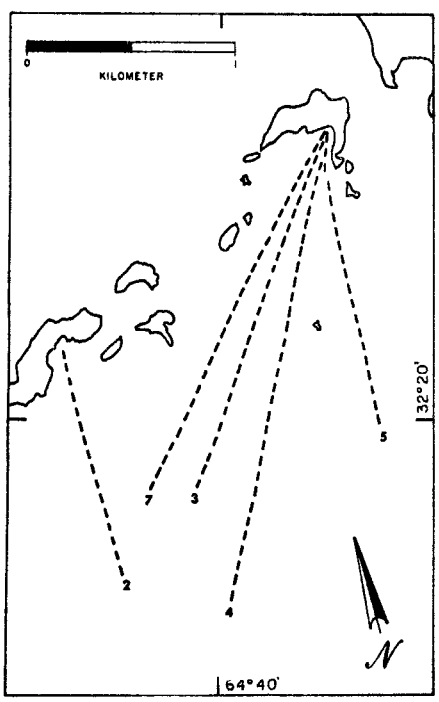

Fig. 2. Approximate courses of hatchlings released off Nonsuch South Beach and Howard Bay Beach in 1970.

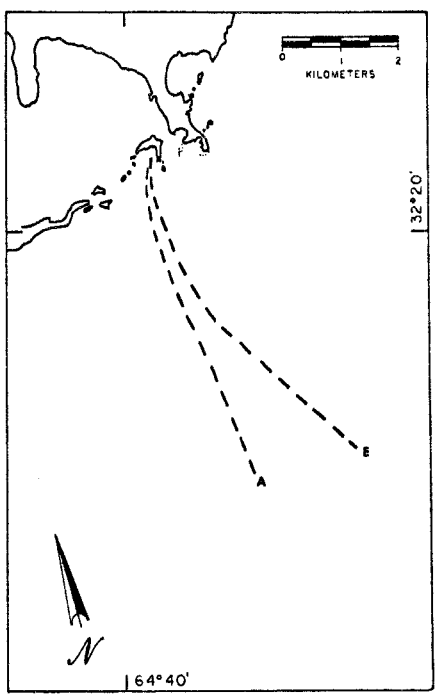

Fig. 3. Approximate courses of hatchlings tracked for 6·00 km to 6·48 km from release point on Nonsuch South Beach, 1971.

speeds of a south-trending longshore current were measured by timing an empty corked bottle as it floated a known distance.

Results

Bermuda

The travel paths. Of the eighteen turtles tracked off the beaches facing the open ocean, six held courses approximately at right angles with the shore of release, ten diverged at angles of from 5° to 35° east and west of this course, and two circled aimlessly in Nonsuch Bay. Of the eight turtles released on Nonsuch North Beach, where the outlook is cluttered with rocks and promontories, three swam into the harbour against the tide, and five swam toward the open sea. Although six of the eight turtles tracked for more than 2 km veered as much as 40° east and west of their initial headings, in the case of Nonsuch North Beach where the turtles had a choice between the open ocean and the harbour, the departure heading was considered the course taken after the initial choice between these two opposing directions had been made. Once having established a course, all the hatchlings held to it, regardless of direction, with what seemed clearly non-random accuracy and consistency. None veered more than 5° to 10° within the first 1·50 km. However, when tracked beyond this distance, six were deflected, probably due to currents, although these were not measured. When a course was obstructed by breaking reefs, masses of drift or the tracker-tender boat, the turtle in every case swam over, under or around the obstacle and continued on course. Once in the sea, the hatchlings of a given batch never remained together or appeared to influence each other in any way. Distances covered and directions taken are indicated in Tables I and II.

Swimming rate. The average swimming rate for the twenty-four turtles tracked for 0·60 to 6·48 km was 1·57 km per hour. This is much slower than the sudden spurts of speed that captive hatchlings sometimes display, but faster than the deliberate paddling they do in foraging.

Breathing interval, swimming depth and diving. At 5 to 10 s intervals the swimming hatchlings would rise to the surface, tread water momentarily with all four limbs, breathe and then swim on at an average depth of 20 cm, diving at varying intervals to approximately three metres.

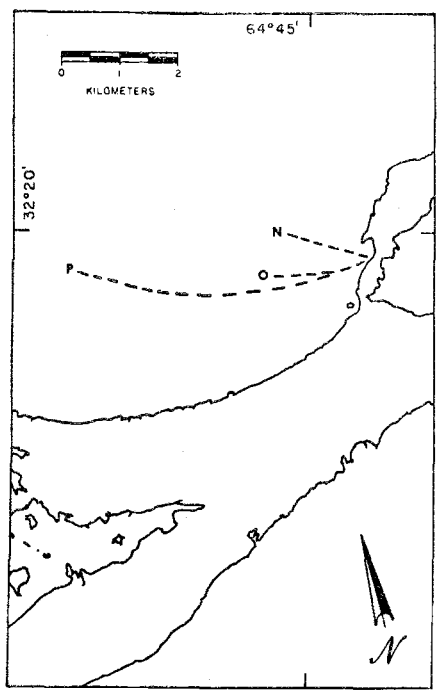

Fig. 4. Courses of hatchlings released at Shelly Bay Beach, 1971.

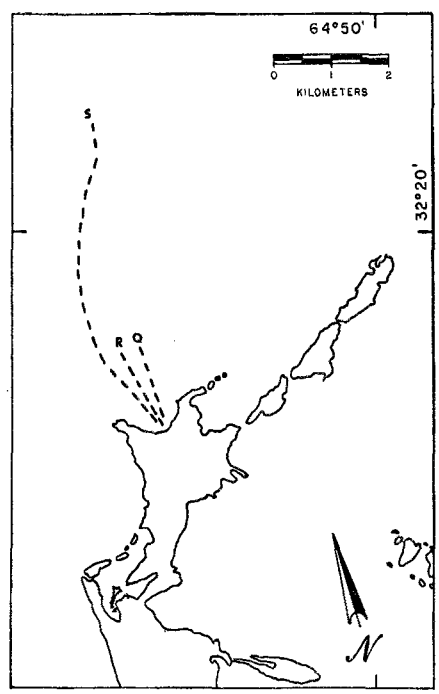

Fig. 5. Courses of hatchlings released at Long Bay Beach, 1971.

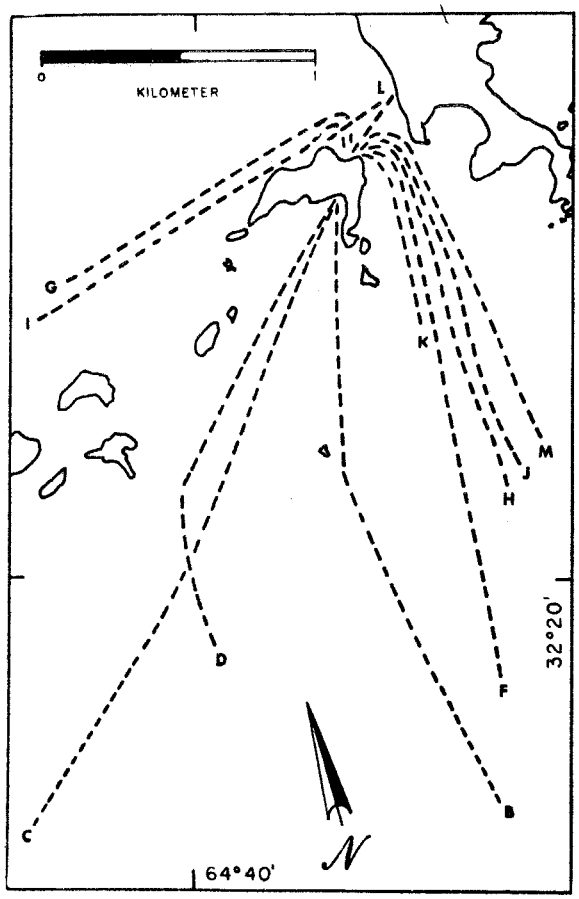

Fig. 6. Courses taken by hatchlings released at Nonsuch North Beach and Nonsuch South Beach, 1971.

Dives were sometimes caused by the approach of a boat. A similar reaction to over-flying aircraft suggested that hatchlings dive to escape predatory birds, which later was found to be true at Tortuguero. In most dives the hatchling resumed horizontal swimming at the maximum depth attained, until it again rose vertically to the surface. The maximum duration of such dives was 2·5 min.

Feeding. One aspect of the lost-year puzzle is the uncertainty whether and how hatchlings feed in the open sea. None of the turtles tracked in the present tests had been fed prior to release; all, in fact, had fresh umbilical scars. The only case of feeding observed during a tracking run was that of turtle E, which stopped swimming, dived down 1 m, and systematically ate a small comb-jelly.

Resting and lodging. Most of the hatchlings swam steadily throughout the observation periods. Turtle E stopped briefly at 14.00 hours, after 5 km of steady swimming, and floated on the surface with the flippers pressed flat along the carapace in the sleeping position. Turtle S, (Plate XII, Fig. 7) after swimming for 5·86 km, crawled up into one of several patches of sargassum weed and stayed there, swimming from one small clump to another for approximately one-half hour, after which contact with it was lost during a change of trackers. A careful search of the weeds where this hatchling was last seen, and of nearby patches, suggested that it had suddenly left the vicinity; and though we searched out along the way it had previously been swimming we were unable to re-establish contact. This hatchling could have been taken by a predator. In 1970 another turtle tracked off Nonsuch South Beach lodged in a small patch of weeds after swimming for 2·30 km.

Predation. Although it is generally assumed that predation by fish is extremely heavy during the period after hatchlings enter the sea, few definite observations have been recorded. During the present experiments, two of the turtles tracked were lost to fish. Turtle B was seized by a belonid (needle fish) *Tylosurus* sp., but was dropped when the tracker swam up and frightened the fish. Turtle K was eaten by a small barracuda, *Sphyraena barracuda*. Two other turtles were approached and nudged by bonitos, *Seriola rivoliana*, which quickly retreated as the tracker approached. In other cases, fish of various kinds swam beneath turtles but made no move toward them.

Observations on turtles released directly into the sea. Five hatchlings were released directly into the sea, out of sight of land at turtle eye-level (approx. 5 km) and without prior experience in crawling on the beach or swimming. Immediately after release these hatchlings dived at a nearly vertical angle to depths of up to 3 m, sometimes swimming aimlessly in circles or zigzags at this depth. After approximately one and a half minutes they would struggle to the surface, paddle in circles breathing rapidly with their heads above water, then repeat the same diving behaviour. Because their erratic behaviour made it difficult to follow them, all but one were lost within the first half hour of tracking. This one turtle was observed to take an oriented heading for 10 min after 0·5 hr of circling.

Table I. Preliminary Trials Off Nonsuch South Beach and Howard Bay Beach in 1970

Turtle	Release site	Date	Approximate course	Time tracked (Eastern Standard)	Approximate distance tracked (km)
1	Nonsuch S (hatchery)	18 Oct.	Circled aimlessly in Bay	12·00 12·40	—
2	Howard Bay (hatchery)	19 Oct.	S.E.	14·30 15·00	1·18
3	Nonsuch S	20 Oct.	S.W.	11·30 12·40	1·82
4	Nonsuch S	20 Oct.	S.W.	11·30 12·40	2·30
5	Nonsuch S	21 Oct.	S.E.	10·15 11·10	1·48
6	Nonsuch S	21 Oct.	Circled aimlessly in Bay	10·15 11·00	—
7	Nonsuch S	21 Oct.	S.W.	12·00 13·00	1·98

Tortuguero

Results of the tracking at Tortuguero are shown in Fig. 8 and Table III. Although the travel paths recorded seem obviously non-random, they were evidently influenced by a southerly longshore current measured at speeds from 0·37 to 0·65 km per hour which affected the speed of the turtle when it was swimming against the current. The average speed for all three turtles was 1·49 km per hour. Further work is necessary in order to determine the extent of this influence beyond the first 2 km at sea. Unlike the situation at Bermuda, the diving behaviour and surfacing intervals of the Tortuguero hatchlings travelling during the daylight hours are affected by the predatory attention of the frigate-birds that usually occur off a natural rookery and are present at Tortuguero. Although no underwater observations were possible because of the sharks that abound in the area, it was possible to keep the hatchlings in sight from a position far enough away from them that the frigate birds would attack freely. The hatchlings showed obvious evasive activity, diving quickly with each near approach of the bird. During these periods, the swimming rate decreased.

Discussion

The observations recorded here prove the feasibility of the direct tracking of hatchlings by either a swimmer or observers in a boat. The data gathered so far, though not extensive, suggest some generalizations that may bear on the lost year puzzle in sea turtle ecology as follows: (1) Green turtle hatchlings swim steadily on an oriented heading after crossing the surf and passing reefs or other shore zone obstructions. (2) The departure courses are approximate extensions of the paths taken by the hatchlings in crawling to the sea from the nest. (3) The headings are not maintained by visual reference to a fixed object on shore, although what determines a departure direction is still unknown. (4) The departing turtles swim steadily, near the surface, mainly at depths of 20 cm or less. (5) Although the turtles may pause in their swimming to feed, only one case of feeding has been recorded, and the main drive at this stage appears to be to get beyond the reef area to offshore regions of lower predation. (6) The turtles are able to dive at depths of 3 m or more, which may allow them to escape from predation by birds. (7) Predation by fish occurs most frequently when the hatchling is crossing a reef area. (8) Travel may be temporarily interrupted, even in daytime, for rest. During such periods the turtle floats with flippers flattened on the edges of the carapace, in the typical sleeping attitude. (9) Refuge is taken, at least occasionally, in sargassum rafts encountered along the way. (10) Unlike hatchlings released on a

Table II. Trials Off Four Sites of Release in 1971

Turtle	Release site	Date 1971	Hr between Emerging and release	Approximate courses	Time tracked	Approximate distance tracked (km)
A	Nonsuch S	16 Oct.	15	S.E. then S.	12.20 15.30	6·00
B	Nonsuch S (hatchery)	16 Oct.	14.25	S.W. then S.E.	12.05 14.00	2·38
C	Nonsuch S (hatchery)	16 Oct.	15.5	S.W.	12.40 14.30	2·63
D	Nonsuch S (hatchery)	17 Oct.	25	S.W. then S.E.	10.15 11.45	1·82
E	Nonsuch S (hatchery)	17 Oct.	25	S. then S.E.	10.35 14.30	6·48
F	Nonsuch N	18 Oct.	14.25	S.	11.05 12.35	2·14
G	Nonsuch N	18 Oct.	14.25	N. into harbour then S.E.	11.05 12.30	1·36
H	Nonsuch N	18 Oct.	14.25	S.W.	11.05 12.05	1·47
I	Nonsuch N	18 Oct.	14.25	N. into harbour then S.E.	11.05 12.30	1·42
J	Nonsuch N	18 Oct.	14.25	S.E.	11.05 12.05	1·49
K	Nonsuch N	18 Oct.	14.25	S.	11.05 11.45	0·70
L	Nonsuch N	20 Oct.	19.25	N.W. then S.E.	14.15 15.00	0·60
M	Nonsuch N	22 Oct.	18	S.E.	15.15 16.00	1·48
N	Shelly Bay	23 Oct.	11	N.W.	11.00 12.20	1·50
O	Shelly Bay	23 Oct.	12.5	W. then N.W.	12.35 13.30	1·68
P	Shelly Bay	23 Oct.	13.5	W. then N.W.	13.40 15.30	5·16
Q	Long Bay	24Oct.	2.7	N.	10.10 11.00	1·50
R	Long Bay	24 Oct.	2.7	N.W.	10.10 11.15	1·52
S	Long Bay	24 Oct.	2.7	N.W. to N.E. to N.	10.10 13.15	5·86

Table III. Preliminary Tracking Trials off Tortuguero Beach Costa Rica, 1974

Turtle	Date	Approx. course	Time tracked	Approx. distance (km)	Current direction and velocity (nautical miles per hr)	Surfacing intervals
I	24 Sept.	S.E.	9.17 10.22	1·65	0·65	Every 7·2 s decreasing to 4 s when frigate-birds appeared.
II	25 Sept.	N.E. then E.	10.50 11.50	1·22	0·37	Not recorded.
III	26 Sept.	S.E.	9.05 10.07	1·70	0·65	Every 8·3 s.

beach and allowed to go through the surf in a natural way, those released directly into the sea appeared frantic and completely disoriented. This behaviour suggests that the experience of a natural ontogenetic sequence of orientation and locomotor responses may be necessary developmental grounding for the performance of later and quite different functions.

In sum, the observations appear to indicate that hatchlings engage in active, energetic, oriented travel for at least 4 hr after they enter the sea. The fundamental adaptive reason for the juvenile travel-drive may be, as has been suggested, to reach longshore currents in which sargassum rafts serve as a refuge and feeding place.

Acknowledgments

I want to thank the many who assisted in tracking hatchlings off Bermuda. In particular, I would like to thank Steve, Tom and David Carr, Peggy Hammond, Eric and Brooke Herter, David Braga, Jim Burnett-Herkes, David Lonsdale, Simon Holland, Penny Salter, Mr and Mrs Richard Slaughter, Rob Seaver, Jesse Goodyear, David Wingate, Campbell O'Connor, Deloy Robinson, Alex Shoumatoff, and my parents, Dr and Mrs H. C. Frick. For assistance at Tortuguero, I would like to thank Chuck Carr and Judy and Josh Polan. I am grateful for the the information Dr Joseph Seronde provided on technical aspects of coastal navigation. I would also like to thank Shirley Robbins and Dawn Brown for help in typing the manuscript. Professor and Mrs A. Carr helped with the tracker-tender during the Bermuda experiments. Professor Carr and Dr David Ehrenfeld made helpful suggestions regarding organization of the manuscript. In Costa Rica, logistic assistance and facilities were provided by the Caribbean Conservation Corporation, and by the Oceanography Section,

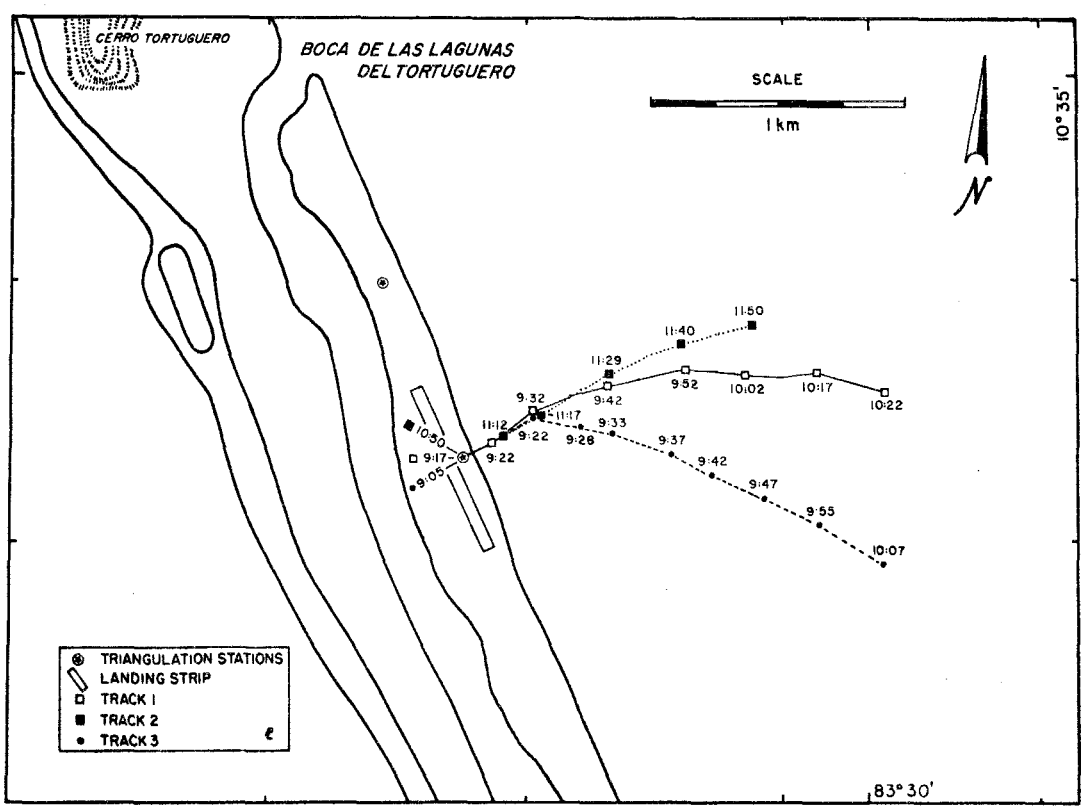

Fig. 8. Courses taken by hatchlings released on Tortuguero Beach, Costa Rica, 1974.

National Science Foundation, N.S.F. Grant GA 36638, under which closely related research is being conducted.

This study is catalogue No. 655—Bermuda Biological Station for Research.

REFERENCES

Caldwell, D. (1968). Baby loggerhead turtles associated with Sargassum weed. *Q. Jl. Fla. Acad. Sci.*, **31**, 271–272.

Carr, A. F. (1966). Adaptive aspects of the scheduled travel of *Chelonia*. In: *Animal Navigation and Orientation* (Ed. by R. M. Storm), pp. 35–55. Corvallis, Oregon: Oregon State University Press.

Carr, A. F. & Ogren, L. (1960). The ecology and migrations of sea turtles. 4. The green turtle in the Caribbean Sea. *Bull. Am. Mus. nat. Hist.*, **121**, 1–48.

Ehrenfeld, D. W. (1968). The role of vision in the sea-finding orientation of the green sea turtle (*Chelonia mydas*). 2. Orientation mechanism and range of spectral sensitivity. *Anim. Behav.*, **16**, 281–287.

Mrosovsky, N. & Shettleworth, S. (1968). The wavelength preference and brightness cues in the water finding behavior of sea turtles. *Behaviour*, **32(4)**, 211–257.

Parker, G. H. (1922). The crawling of young loggerhead turtles toward the sea. *J. exp. Zool.*, **6**, 323–331.

(*Received* 27 *June* 1972; *revised* 14 *May* 1974; *second revision* 1 *April* 1975; *third revision* 17 *September* 1975; *MS. number:* A1344)

PLATE XII

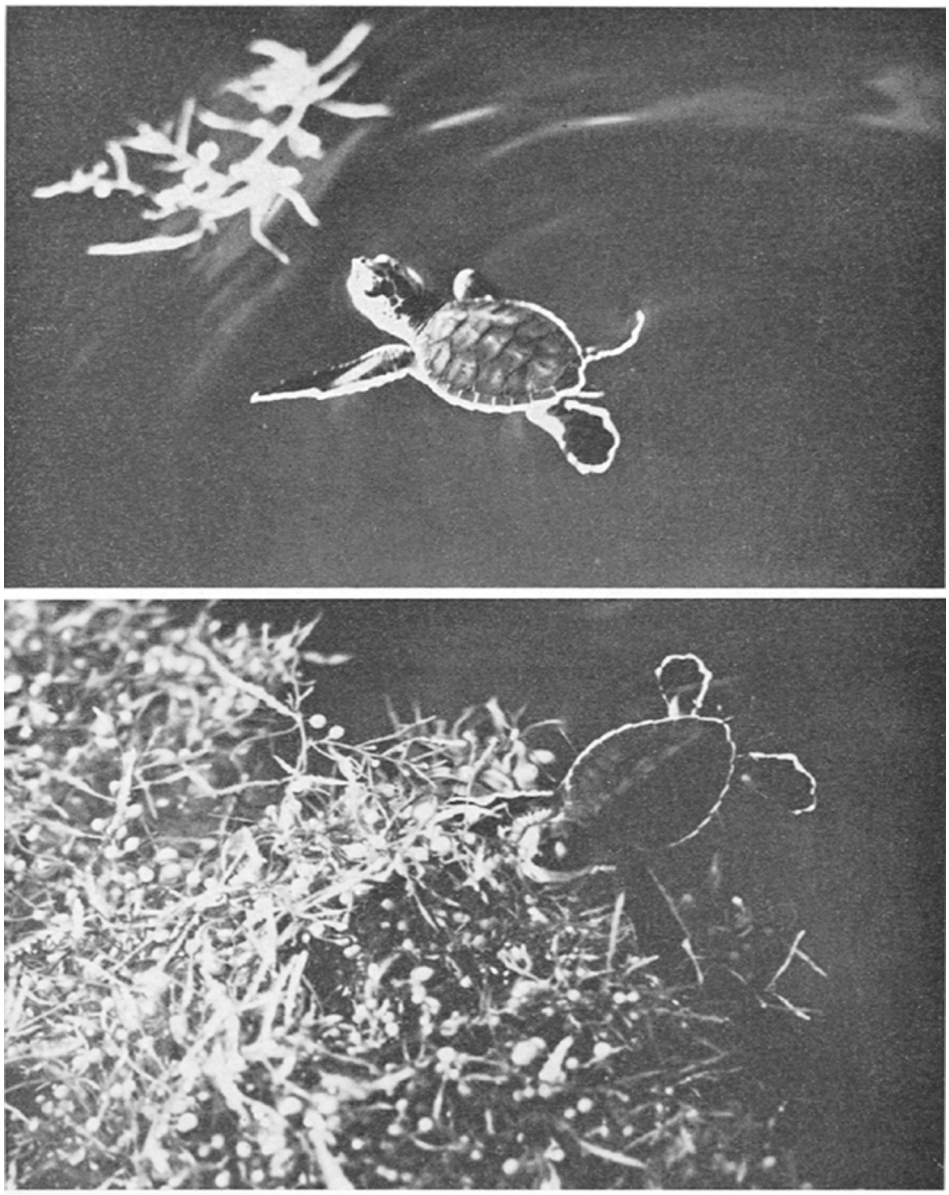

Fig. 7. After swimming seaward for 5·86 km from the beach on the northwest coast of Bermuda a green turtle hatchling approaches (upper), climbs into (lower) and rests in a large patch of sargassum weed. Photograph credit to Richard Slaughter.