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# ORIENTATION PROBLEMS IN THE HIGH SEAS TRAVEL AND TERRESTRIAL MOVEMENTS OF MARINE TURTLES

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STUDIES of American sea turtles made during the past six years have been mainly concerned with piecing out the fundamental natural history of the five genera. One important aim, to establish the long-suspected fact of long-distance migration, has been virtually achieved; but a number of problems await techniques for maintaining contact with the animals through marked changes in ontogeny, ecology and range. Besides the still unanswered questions of ecological geography, a complex of problems concerning orientation responses, possibly ranging from simple taxes to celestial navigation and piloting by obscure landmarks, will probably be solved only through the use of distant monitoring and electronic tracking methods.

In a tagging program carried out at Tortuguero on the Caribbean Coast of Costa Rica 2000 mature female green turtles (*Chelonia*) have been marked. There have been 64 post-season returns, all but two from outside Costa Rican waters. The recoveries spread throughout the western Caribbean. Such data almost prove that periodic migration is occurring, but not quite. The green turtle nests on a three-year cycle, with a subsidiary two-year cycle shown by thirty to forty percent of the re-arrivals at the Costa Rican nesting ground. We have retaken turtles in Costa Rica after two or three-year absences on many occasions, and because there is no resident population in Costa Rican waters these returns reinforce evidence that migratory commuting between Tortuguero and distant pastures occurs. The site tenacity shown by both these long-term rearrivals, and by turtles renesting three or four times during a single season, add further circumstantial evidence. One way of proving the case would be through recapture at Tortuguero of turtles tagged there on previous arrivals, recaught on the pasture ground, and released again. We have so far made no effort to persuade fishermen at the Miskito Cay pastures and elsewhere to release tagged turtles. If we had, the expected recovery number would have been only 1.9 turtles.

To inch a little closer toward direct proof of migration we undertook a tagging program on Ascension Island in the middle South Atlantic. The nesting colony there shows trenchant seasonality, disappearing completely when nesting is done; and the resident population of the Brazilian Coast evidently nests nowhere along the mainland shore. The hypothesis that the Brazilian turtles go to Ascension to nest thus seemed reasonable. During the Spring of 1960 Harold Hirth tagged 206 females at the island. That the five returns to date have all been from the coast of Brazil seems as near closing the circle of evidence as can be expected from a one-way tagging program. Overshadowing such bits of progress, however, is our complete ignorance of routes and schedules of the journeys and of the cues and senses by which they are guided. This will be relieved only when we are able to keep in protracted contact with the traveling animals.

## TRACKING WITH HELIUM BALLOONS

Once it had been shown to be able to make appropriate landfalls after long travel through the open sea, the green turtle became a promising subject for orientation research. We have made crude tracking tests with three species of sea turtles, using helium balloons rising from towed styrofoam floats (see Fig. 1). In eight of these the animals were released on the beach after nesting had been completed, with the aim of learning what a female turtle does and where she goes for the twelve-day interval between her renesting emergences of a single season. The other trials were made off shore and out of sight of land. Tracking was done with transits, alidades, or an optical range finder. Results have ranged from the ambiguous to the meaningless. Gross procedural troubles cancelled most of the efforts. In the inshore tests the simple act of getting the equipment through surf presented problems. It took several trials to show how deep a turtle cruises, and thus how long the towline should be to preclude dragging the float under, and it was found that nothing could forestall the occasional erratic sounding of a subject passing over a rockpit or other attractive foraging site. There are other disadvantages. Helium escapes in long tests, or the balloons burst if overheated. Hydrogen is looked on with disfavor by boat skippers, and any balloon tracking is likely to end if more than a slight breeze blows or the towline is dragged through floating vegetation. Curious crews of shrimp boats have aborted two of our runs.

Visual tracking also carries the inherent drawback of loss of contact at night. Although this can be circumvented by installing a light to rise with the balloon, such embellishment of the turtle's celestial sphere blurs the experimental picture. Balloons may likewise mar the daylight tests, but the likelihood that a near bright light overhead would confuse the stellar pattern seems considerably greater.

It is thus clear that when serious tests are undertaken telemetry must be used, and as was said, the genus *Chelonia* seems in some ways a specially good prospect for such manipulation. The most reliable and predictable travel motivation would be found in mature females, which usually weigh from 250 to 350 lb. The bulk and strength of these, and the free bony overhang of

FIG. 1. The rig used in balloon tracking tests. The styrofoam float (held by man at left) was fastened to the hind edge of the shell with 30 ft of monofilament line. Two balloons rose on 10 and 15 ft lines. The tow-line swivel was attached to the shell with thin iron wire, designed to rust away within a short time and free the turtle of the rig. All turtles tested were marked with standard fin tags.

the shell make extreme miniaturization of equipment unnecessary and permit the bolting down of apparatus without undue irritation to tissue. Another advantage is the relatively slow speed of travel—evidently not more than 20 to 30 miles a day in sustained migratory swimming. The aquatic medium is of course unhandy, but at least the subject breathes air and must rise to blow, at intervals of the order of one to three minutes while active, and two to thirty minutes when at rest. The exposed fore margin of the shell is awash during breathing, or at most no more than an inch or so out of water. Thus if radio tracking were used antennal elevation would be slight except where emergence occurred on the crest of a wave. In this regard a sea turtle will be a more refractory subject for radio tracking than a flying bird, but much easier to work with than a fish.

The including of Chelonia among proved open-sea navigators has indirect bearing on the troublesome question of sun orientation. Because of the absence in the watery landscape of any fixed reference for appraising sun azimuth the sun-arc theory seems inapplicable in over-water orientation. Pennycuick (1960) has suggested that a bird might find its position by measuring (1) the altitude of the sun and (2) the rate of change in the altitude of the sun. Schmidt-Koenig (1961) has shown experimental grounds for doubting that such a navigational grid is actually used. If we are to retain a sun navigation theory to explain overwater guidance in the daytime it would seem necessary to fall back on the idea that azimuth may be measured by using the trend of the waves as a reference. That sea turtles do their navigating from beneath or at the surface of the water would seem to make wave-trend unavailable to them as a reference, and leaves us with no theory to account for their feats of high-seas guidance.

## TRACKING COMPLICATIONS

In navigation testing, or in one sort of navigation test, a requisite almost as important as maintaining contact with the animal is knowing what it is trying to do, where it wants, so to speak, to go. Sea turtles present a considerable array of adaptive travel drives, and while the aim of some of these can be assumed by the observer, others, no less strong, are without evident aim. The so-called infantile frenzy of the hatchling is a good example. Newly hatched green turtles placed in a tank swim constantly and with frantic energy along and against the walls. If the tank is differentially lighted they congregate at the lighted end; but even there they keep up their desperate swimming for days or weeks. This may mean nothing; but more likely it is associated with the complete disappearance of all kinds of young sea turtles from human sight for at least a year following the crossing of the breaker line at the nesting beach. The swim-frenzy suggests that young sea turtles travel constantly for a long time, and their disappearance seems to confirm the suspicion. Keeping in touch with them would solve one of the most important remaining gaps in a complex life cycle. It seems likely that light-arena experiments with young at this stage may reveal that a latent compass sense is released with the culmination of the chain of events that takes them from the nest through the breakers. But little beyond that can be done experimentally until field tracking has shown what use the compass sense is put to in nature, and an accurate forecast of goal-motivation can be made.

This unpredictability of the motivation of experimental material promises to be the most important obstacle in short-run tracking studies with sea turtles. The difficulties are illustrated by the results of six tracking tests we made off Cedar Key, on the Gulf Coast of peninsular Florida. The turtles were mature female loggerheads taken just after emerging to nest, but before actually starting the process. The nesting drive is exceptionally urgent in marine turtles. At our Costa Rican camp they have come ashore dragging big buoy logs used to mark them for the coasting turtle boat that used to pick them up out of the sea where the hunters had released them. They also, as was said, show a strong site tenacity which, in the multiple nestings of a given season may bring a turtle back to the same short section of a twenty-mile beach, or to one of many similar little coves around an island (Carr and Hirth, 1962); or to one among many small islands in a close-knit system (Hendrickson, 1958). This combination of reproductive drive and site discrimination suggested using displaced ovigerous female turtles in heading and course-segment tests.

The six Cedar Keys trials were exploratory, and we soon saw that they were defectively arranged. They overcomplicated the navigation problem by placing the peninsula of Florida between the animal and its assumed goal. Release in the Atlantic off the nesting beach would have been more logical. The Cedar Key area was selected simply because the line of daybeacons off the reef there made optical tracking more feasible than it would have been in the Atlantic, where it would have had to be done from small boats in rough water.

## TRUE OR "NONSENSE" NAVIGATION

In tests such as these there are three separate questions to be asked: (1) whether the animal is navigating or moving at random; (2) whether the animal is homing, and (3) whether the animal is homing successfully, and if so by what route (i.e., whether if extrapolated, the course, with later corrections would take the animal home. The alternative situation would be what Matthews called "nonsense" navigation).

In the Cedar Key experiments it was not possible to assume in advance what homing direction would be appropriate. How would a Daytona Beach sea turtle, hauled on her back in a covered truck at night to the other side of the Peninsula interpret her problem? Would she appraise her position as simply "out at sea", and head for the somehow-detected nearest shore? Or, reacting in a more sophisticated way to the same assumption, would she head due west—the way to go if she had indeed been displaced seaward in the Atlantic? Or, assuming that she had a sound familiarity with the celestial sphere but no inbuilt sense of detailed earth geography, would she head for home by the airline route—in this case straight across the peninsula? Or, as some birds evidently can do, should the turtle be expected to show that most advanced of all orientation capacities: full map sense—earthmap as well as star-almanac—and either head south to circumnavigate the peninsula without seeing it, or move in and follow the shoreline around to her home beach. Obviously there is no knowing any of this *a priori*, and no sure way of extrapolating from short sample segments of courses taken. Such ambiguities are bound to complicate most heading tests with aquatic animals in shore waters.

Although taken as a group the six tests show little agreement in initial headings, there are suggestions of nonrandomness in some of the individual

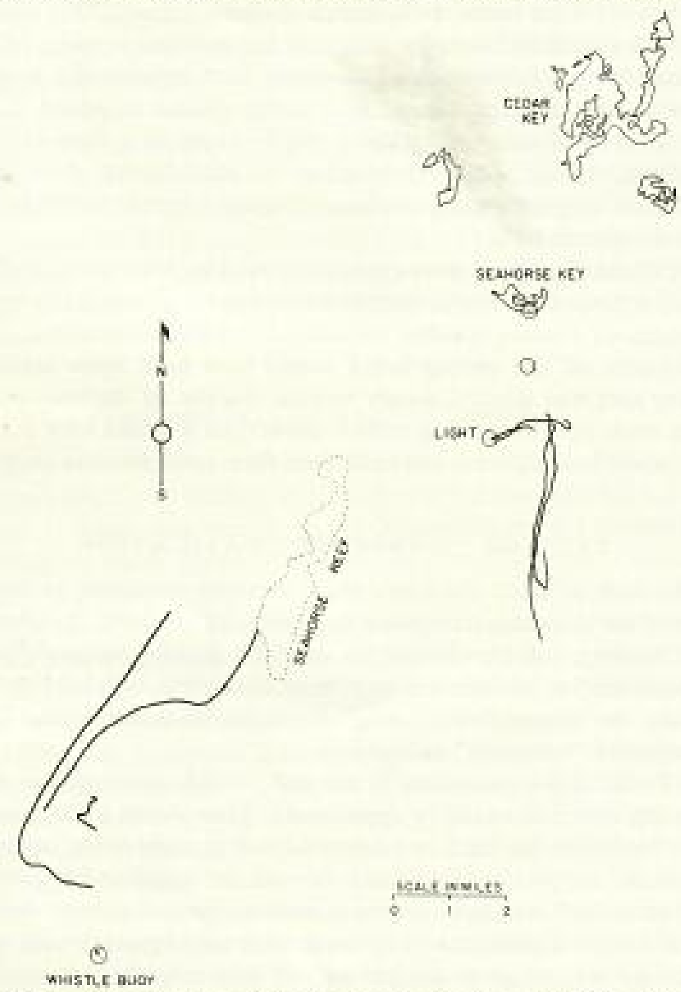


FIG. 2. The Cedar Key area of Florida, showing location of tracking tests made in 1960 with female loggerhead turtles hauled across the Peninsula from Fort Pierce, where they had just emerged to nest but had not nested. The three courses at left were six-hour runs tracked with two alidades, one located on a beacon, the other on a fifty-foot boat. The three course segments at left were tracked with transits on two daybeacons a mile apart, the two southerly courses on July 9, the other on June 26. The time involved in these is shown in Fig. 3.

routes. The two southerly courses shown in Figs. 2 and 3, particularly, seem oriented. They were plotted from tracking observations at two-minute intervals and are probably quite accurate. Granting that they prove nothing

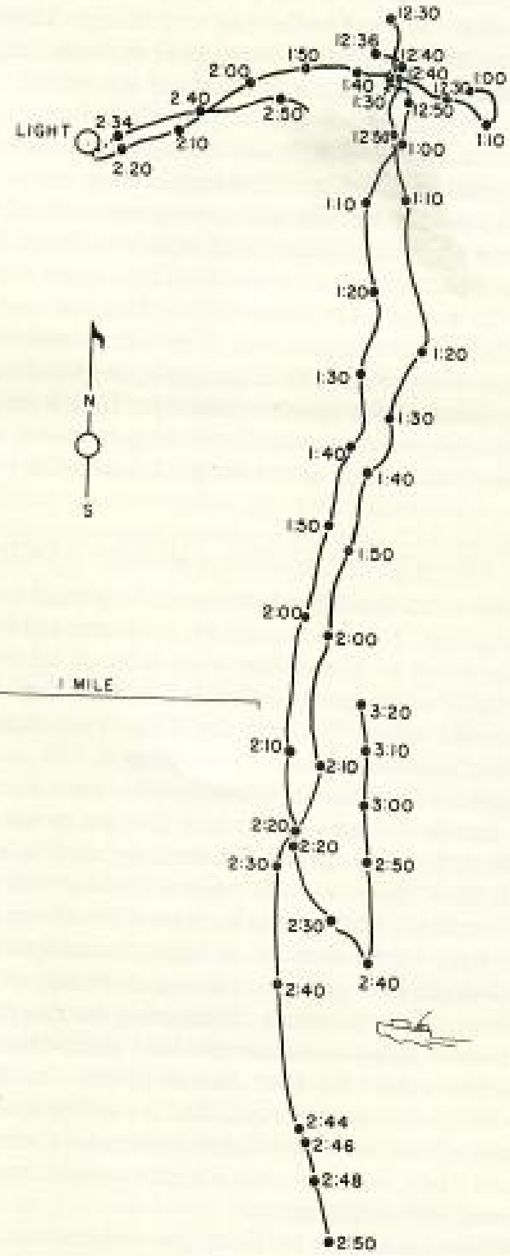


FIG. 3. Courses of three loggerheads tracked off Cedar Key (see Fig. 2). The turtles were marked with helium-filled balloons and tracked by triangulation with two transits, with sightings made at two- and three-minute intervals.

about heading-motivation, it is still necessary to ask whether the turtles were moving at random, or were navigating or piloting. They were well out of sight of the mainland at all times. From their depressed angle of observation no fixed landmarks were visible for most of the period of their travel. A contour chart of the area shows no way in which isobaths might have been used for reference. The courses cut across a mosaic of water types and through current that varied in direction and strength along the way. Because there were extended periods when the turtles were not in visual contact with each other (they were always in sight of each other's balloons, but this cannot be assumed to have been a bond between them) the stature of the performance is enhanced by its having been done twice. The one conceivably available landmark was a fairly continuous rank of cumulus clouds over the hinterland fifteen or twenty miles away. That a navigating animal should fail to use such a source of guidance data appears unlikely. That it could have kept the turtles so precisely on their southerly heading, however, seems improbable. Perhaps the same can be said of sun arc guidance in short runs such as these.

## SUGGESTIONS FOR FUTURE STUDIES

All that these and a few other balloon-tracking trials have done is suggest lines of investigation. It will be immensely profitable to know merely whether sea turtles can travel in nonrandom ways without reference to landmarks. The zoogeography of the group indicates that they can. Balloon tests seem unlikely to furnish solidly confirmatory data. This then is a clear case in which telemetric intervention seems promising.

Once the capacity for open-sea orientation has been experimentally demonstrated, tests can be devised to show how it is put to use in going from one place to another: first through familiar territory, then in homing or position-finding. It is here that sea-turtle natural history will make the greatest demand on telemetry. Throughout its travels the routes the animal follows are obscure. Baby turtles hatched at Ascension and adults returning from there to Brazil might drift passively with the current to within short distances of home territory. For the mature turtles going the other way, however—out to the little oceanic island from the mainland shore—there are at least three logically possible routes: the Gulf Stream system, the Brazil current–West Wind Drift–Benguela current circuit, and the airline upstream route against changing slants of the three-knot South Equatorial Current. The last seems by far the most likely, but it presents a highly complex navigation problem in terms of set and drift displacement.

In the Gulf-Caribbean area we know green turtles well at only three stages of development. Mature females come to Costa Rica to nest, and mature males accompany them to fertilize eggs for the next reproductive period. Hatchlings emerge from the eggs laid there. On the central Gulf Coast of

Florida half grown (10–90 lb) green turtles show up in numbers in April and disappear in late October. All the rest of the life cycle is obscure. Consequently, there are few places in the range or life cycle where samples can be counted on to take predictable headings, and the significance of headings or short course segments must be appraised with the greatest care.

There is one aspect of the orientation life of sea turtles that is easily subjected to manipulatory study, if not easily understood. This is the short, eventful journey of the hatchling group from the nest to the sea. Navigation is evidently not involved in this, because hatchlings taken from a nest on a north-facing Atlantic beach and allowed to emerge on a southwest-facing Pacific shore go through the same behavioral stereotypes and reach the water with the same success as nestmates left at home. Nevertheless, the seafinding venture is a good model for the complex long range orientation feats of the adult. The most fundamental response in the sea-seeking travel appears to be a sort of telotaxis, a tendency to move toward better illuminated sky or toward horizons free of obstacles. But at various points along the route this beacon is supplemented, or overridden, by other information. Shifts, confirmations and reorientations occur all along the way. The hatchling journey thus furnishes insight into the nature of instinctive guidepost pathfinding, and supports the growing belief of navigation students that travel orientation is always a composite process.

## HATCHLINGS-TO-THE-SEA PROCESS

The trip to the sea begins some 28 in. beneath the sand (see Fig. 4) where the hatched-out turtles find themselves in a chamber in which collapse of the spherical eggs has given them a bit of headroom. It has been shown that the trip to the surface is not a climbing through the sand by separate individuals, each under the urge of negative geotaxis, as was once supposed. There is some struggle upward, but the most effective factor in the emergence process seems to be the rising of the whole nest chamber, brought about by a proto-co-operative group thrashing, triggered by the downtrodden hatchlings on the floor of the nest. The generalized thrashing of the bottom layer of turtles sends a pandemic of activity through the whole imprisoned group. Each burst undercuts the walls, saps the ceiling, and tramples sand into a rising floor. The group spasms are thus automatically converted into a crude division of labor, the net result of which is the upward movement of the roomful of turtles to the surface. Turtles hatching separately at similar depths show markedly reduced survival.

The time involved in the emergence process is generally about a week. Observations through a glass nest-side introduce artifacts: enough light to see by is an unnatural factor in the nest environment, and so is the glass replacing collapsible sand of the wall. For an adequate study of this interesting case of social facilitation, the need is for instrumentation to monitor the position and activity of individuals of the sibling group throughout the emergence period.

Once out on the surface the problem the hatchlings face is finding the water, which more often than not is out of sight behind dunes, bushes, driftwood or other obstacles (see Figs. 5–7). They peer about and then start moving, and

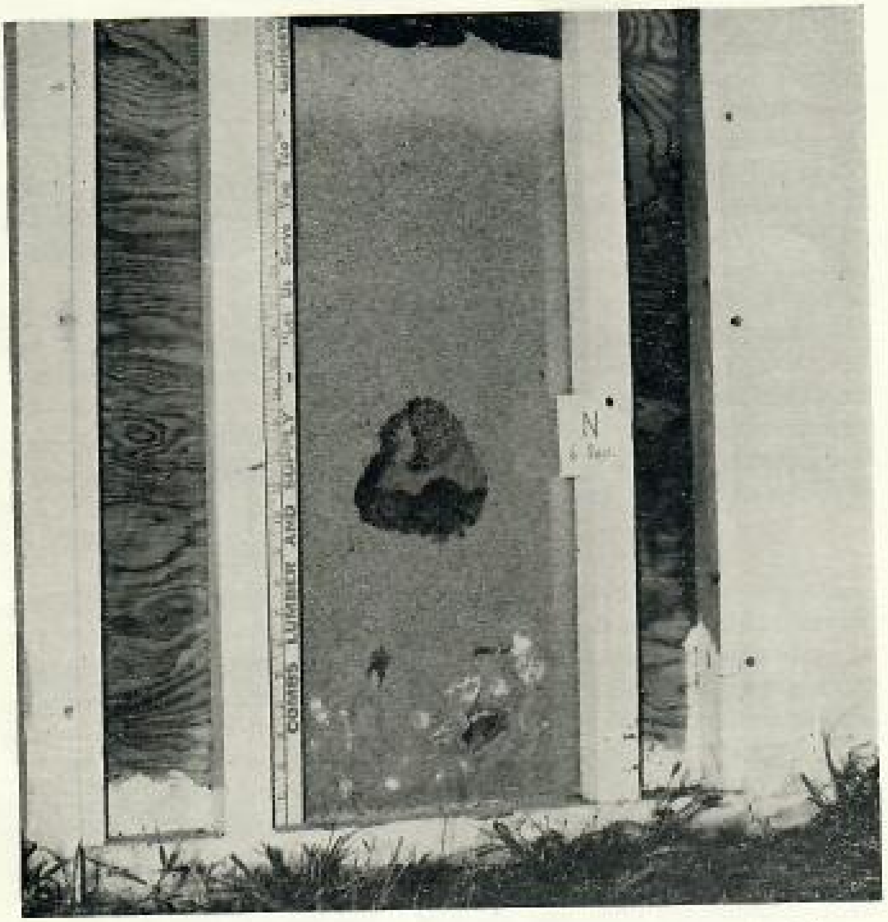

FIG. 4. The rising nest chamber of a group of hatchling loggerhead turtles. The original position of the egg clutch is shown by the shells at the bottom of the box, where a few abnormal hatchlings also remain. The rest, sixty-five in number, emerged in a group through the automatically co-operative process briefly described in the text.

after short false starts almost always go in the direction of the ocean. They climb slopes, go around logs and scramble through brush and trash, and except for the freaks or weaklings among them seem to have solid confidence in whatever beacon it is that tells them where the ocean lies. They can find it by day or by night. The sun or moon may be shining brightly, over the sea or over the land. The weather may be overcast or even raining.

In spite of considerable work by various people (summarized by Carr and Ogren, 1960) with both marine and freshwater turtles the basic guidepost is

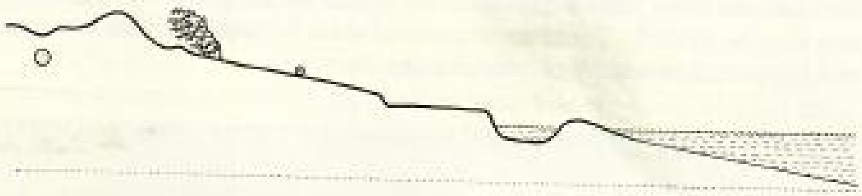

FIG. 5. Composite beach profile suggesting conditions of topography and horizon under which naïve sea turtle hatchlings orient successfully in going to the water. The nest is the stippled circle at left.

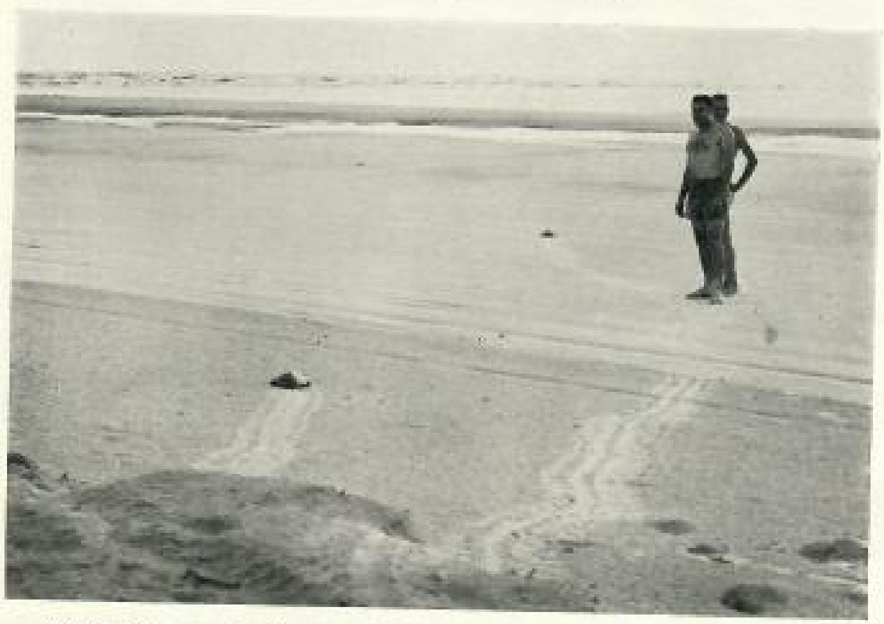

FIG. 6. Two green turtles successfully oriented after having been released at the edge of the dunes at Daytona Beach, Florida. They were part of a group that had been kept nine months in two-gallon tanks in the laboratory, after hatching at Tortuguero, Costa Rica. They had never seen the sea. Their seaward heading was not disrupted by the swash channel and steep bar that can be seen in the background, and which they crossed with little delay.

not thoroughly understood. It has something to do with the illumination of the sky over the sea. If it were a positive light response in the ordinary sense—simple phototaxis—the hatchlings would be expected to go toward the sun or moon, but only very rarely does this occur. On the other hand, when a little turtle moves out from behind an obstruction and the sea-sky comes into better view he is usually stirred suddenly to increased effort. When a wave breaks white under moonlight, little turtles suddenly surge ahead; and it is the same when the surf shows fiery on phosphorescent nights. But even in a flat calm, sea turtle hatchlings seldom fail to find the ocean from wherever the nest may be located. There are occasional mass failures, but they are rare, and in themselves worthy of careful study.

FIG. 7. Train of hatchlings oriented toward the sea (toward upper right) momentarily sidetracked by a nearby patch of white light. The distraction in each case lasted only a few seconds.

After plodding through the soft dune sand the turtles reach the hard tidal flat. Here the light beacon appears to be supplemented by a local signal, probably the combination of hardness, flatness and inclination of the ground. Each turtle suddenly moves faster; the pauses for peering about are less frequent.

The next step comes when sand wet by the highest waves is reached. This brings on another surge of speed and "confidence" and some of the turtles may stumble over their flippers and break prematurely into short flurries of the flying strokes they use in swimming. The touch of damp sand is evidently the cue that brings on the different gait that will be of service only when the water is reached.

Then the farthest reach of a wave slides up the flat and lifts the foremost turtles in a quarter-inch of sheet-flow. The instant they are off the ground the flying swimstroke comes over the hatchlings in an explosion of energy. When the water slides out from under them, they are caught with a new gait that is no good for walking, but as each wave wash comes back, they swim forward a little toward the surf.

This "learning" to swim, seems a clear case of releaser effect. It appears to require no practice period at all. It takes place in the tail ends of a few waves and with it there comes a bipolar rheotaxis which causes the turtles to align themselves with the swash and backwash of the current, evidently told by occasional touches of the bottom that the water is in motion and that it goes first one way and then the other.

In any case they keep swimming straight seaward, dashing forward under water for a few feet, then emerging to breathe and look around, then going down and ahead again. When they reach the breakers one expects to see them picked up and thrown back through all of the way they have gone. But as the crest grows white the heads go down. The hatchlings presumably dive for the bottom and go under the plunge of the breaker. This stage of the seaward journey is of course completely hidden but almost surely involves a variety of responses. In waves approaching shore, there appears to be a complex and variable relation between translation, plunge and backwash, and between these and the position of the step in the bottom. While it is not known what a turtle hatchling does inside a breaking wave there can be no doubt of the high survival-stakes involved. There must be strong adaptive adjustments to wave dynamics. If the interplay of forces and responses could be monitored, it would not only help piece out our understanding of an extraordinary chain of orientation responses but might also shed light on the unaccountable absence of nesting colonies of sea turtles along thousands of miles of unused tropical beaches.

Thus, in going from the nest to the sea little turtles make a short, complicated journey toward a destination they have never seen, and use guidance information from a number of sources. Because it is almost surely the same with longer feats of oriented travel, spot assessment of cues seems unlikely to explain how any long course is established and held or where it leads. The ideal technique is radio tracking, or a continuous recording of the position of the migrant throughout entire roundtrip journeys. That such an ideal can even be mentioned seriously is a sign of new times for natural history.

## ACKNOWLEDGEMENT

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## DISCUSSION

BACH: It is most pertinent here to mention Dr. Bullet's experiences. I don't know whether he has published these or not. It is out in California, where the desert meets the sea. He can get these breeding sea turtles, who have never seen the desert, put them on the desert side of the ridge, get desert reptiles who have never seen the sea and put them on the sea side, and they will head in opposite directions and go right to their appropriate places. I don't know why, but they do it.

CORSON: Do all the turtles eventually make it to the sea? Do some of them get lost?

CARR: Few get lost. And they are usually the ones that are trapped or desiccated on the beach. If the sun comes up it drys them out and they dehydrate rapidly. We sometimes can't distinguish between orientation failure and physiological giving up, as it were.

Some of the hatchlings of course are abnormal when they emerge from the egg. Those generally don't join the group migrating to the surface, and they may never get to the top. Some that do don't reach the ocean. Occasionally we see unaccountable 180° reversals of hatchling orientation.

SCHMIDT-KOENIG: Is there a particular time of day when the turtles emerge to the surface?

CARR: They generally emerge in early morning, just before dawn, but not always. That they don't always emerge at the same time is reflected in the fact that they are able to orient toward the sea at any time of day or night. Their guidance capacity is also independent of the weather. Day or night; rain or clear; with sun or the moon over the ocean or over the land, the majority go directly to the sea.

SCHMIDT-KOENIG: Is it possible that the sound of the surf influences them?

CARR: I don't think so. We have only negative evidence, but light seems to be the factor. With one eye blindfolded the turtles go through a little circular detour. With both eyes covered they lose the sea-finding ability altogether.

VOICE: Did you ever try, with the baby turtles, experiments with a mirror? I mean shining the sun on them with a mirror?

CARR: Yes. It disorients them. On two occasions, we have gone down to the beach with a big mirror and flashed it on sea-seeking hatchlings going to the water. Immediately, they lose orientation.

VOICE: They don't come toward the mirror?

CARR: No. I would imagine that the reflection simply blinds them. They will sometimes come toward a gasoline lamp at night.

MULLINS: With regard to the orienting hatchlings briefly attracted by the white goggles, maybe they went on because the glasses didn't wiggle. I wondered if there could possibly be some reaction to motion in the sea light? I mean that somehow the wave modulated the sun and this is why they went after the lantern, too.

CARR: Well, that could be. I just don't know what qualities light over the ocean has that makes it different from the lantern. It is probably not a matter of polarization. I simply don't know whether there is any motion there, whether it's a type of shimmer that they see or not. It's possible.

GRIFFIN: Well, we can see polarization, you know.

CARR: Is the sky a light map to the human eye?

GRIFFIN: No. It's tricky. This may not be of general interest, but it is a special case, whereby the human eye can distinguish the plane of polarization.

TESTER: This is not a question, but more a comment. I think we are getting down to real cases in trying to understand how these turtles actually do navigate—whether they have this ability. Telemetry in radio-tracking may tell us whether or not they are able to do it. But it isn't going to tell us how they do it. We still have to ask this question of the animal, and this is important.

ARONSON: Telemetry will, of course, help tell us how they do it.

CARR: I think this is a logical first step, to find out whether they actually are navigating, or are moving at random.

BERKELEY: I wonder whether you couldn't put a reasonably big permanent magnet on the turtle and then track with an airborne or seaborne magnetometer.

MCLENNAN: Have we considered the use of some sort of sonar technique here?

CARR: With these balloon tests, I think you might get a maximum run of fifteen miles. That would at least tell us that the animal is oriented if the proper statistics were applied. Could sonar increase that range?

The big payoff will come when we can track the Ascension Island migration. There you have got 1200 miles of open sea travel and the animals definitely converge on a six-mile target out in the middle of the ocean after swimming a thousand miles They are obviously oriented and there are no obvious fixed landmarks. There is just no logical question about it. But how can we follow that journey?

VOICE: You would be surprised how good some sonar sets are. You put the transmitters on opposite sides of the shell with an air reflector in between so you could tell which way the turtle was oriented.

GALLER: You are probably aware that there is a radio beacon device, that has been developed, a prototype has been developed, for tracking marine animals. It may be suitable for some of your turtle work.

HAAHN: I wonder if Dr. Carr would expand, for just a moment, on their susceptibility to hearing normal sounds that we hear, and possibly higher or lower frequencies. Might not the use of sonar interfere with this characteristic you are trying to measure?

CARR: There is a distinct possibility that it could. Unfortunately nothing is known about hearing capacity in sea turtles. I think the possibility that the two turtles that took the same southerly course in the slide were maintaining sound contact with one another can't be ignored. It wasn't vision that kept them together—not seeing each other. And I just don't believe that their orientation is fine-scaled enough to reproduce those concurrently swerving courses through that long distance. So we have not ignored the possibility that they emit some sort of squeak or grunt that may be of use in their group travel.

HAAHN: I was under the impression that there was some sort of sonar block that a plane at sea could drop that could be picked up 1200 miles away.

GALLER: I would like to put one damper on this sonar business. The Navy does have portable sonar equipment that can track for 1200 miles, but I suspect you would have to have a platform about the size of a destroyer, at least, to do this.

COCHRAN: I am certain that the transmitter described by Dr. Singer or Dr. Marshall if placed on the back of a turtle, considering the propagation over sea water which is quite good, would have ranges of twenty or thirty miles, provided the turtle would come up to the surface often enough. But certainly, if they can tolerate a low line on a balloon they could also fly an antenna.

VOICE: The question is how high is the antenna?

CARR: They swim fairly deep, but they breathe; so there is no worry about their not coming to the surface. Sometime the antenna would be on top of a wave and sometime in the trough.

TOLLIS: You wouldn't get an achievement record, but you would get a location every time it came up.

GRIFFIN: If you can attach the antenna to the balloon, your problem becomes much simpler.