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Island-finding ability of marine turtles

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Green turtles (*Chelonia mydas*) swim from foraging grounds along the Brazilian coast to Ascension Island to nest, over 2200 km distant in the middle of the equatorial Atlantic. To test the hypothesis that turtles use wind-borne cues to locate Ascension Island we found turtles that had just completed nesting and then moved three individuals 50 km northwest (downwind) of the island and three individuals 50 km southeast (upwind). Their subsequent movements were tracked by satellite. Turtles released downwind returned to Ascension Island within 1, 2 and 4 days, respectively. By contrast, those released upwind had far more difficulty in relocating Ascension Island, two eventually returning after 10 and 27 days and the third heading back to Brazil after failing to find its way back to the island. These findings strongly support the hypothesis that wind-borne cues are used by turtles to locate Ascension Island.

Keywords: magnetic navigation; map; orientation; olfaction; migration

1. INTRODUCTION

'You miss Ascension, and your wife gets a pension', so ran the rhyme to describe the fate of the early pilots flying to Ascension Island, a remote island in the middle of the Atlantic (Carr 1967). However, despite the problems facing pilots, every year thousands of green turtles migrate from foraging grounds along the Brazilian coast, across at least 2200 km of the Atlantic Ocean, to mate and nest at Ascension Island. Today the island hosts one of the largest green turtle rookeries in the world (Godley *et al.* 2001). How the turtles find the island has presented biologists with a conundrum for over a century (Darwin 1873).

An early idea proposed that turtles might detect the island using water-borne odours carried downstream on the west-southwest-flowing South Atlantic Equatorial Current (Carr 1967; Koch *et al.* 1969), but recent empirical evidence does not support this hypothesis, with turtles displaced down current having difficulty in relocating the island (Luschi *et al.* 2001). It has been shown that hatchling loggerhead turtles (*Caretta caretta*) have the ability to perceive the inclination and intensity of the Earth's magnetic field (Lohmann & Lohmann 1996; Lohmann *et al.* 2001) and, consequently, it has been suggested that green turtles might potentially use geomagnetic information to find Ascension Island (Lohmann & Lohmann 1996). However, so far there is no indication of any magnetic navigation ability in turtles from Ascension Island (Papi *et al.* 2000; Luschi *et al.* 2001). For example, green turtles carrying mobile magnets on their head have been found to migrate towards Brazil without any delays, suggesting that other, non-magnetic, orientation information may be used during their trans-oceanic journey (Papi *et al.* 2000), i.e. alternative navigation mechanisms, aside from relying on magnetic information, seem to exist.

Moreover, while animals relying on a magnetic map should be able to compensate for displacements to any site, turtles from Ascension Island caught on their nesting beach and released in the ocean 60–450 km away from it found the island difficult to relocate. Nevertheless, examination of their routes has suggested that the island was more easily located from downwind, possibly thanks to wind-borne information (Luschi *et al.* 2001). To test the theory that the wind may carry navigational information to allow the island to be located, we artificially displaced turtles downwind and upwind of Ascension Island during January 2002 and then tracked their subsequent movements by satellite.

2. MATERIAL AND METHODS

In January 2002, Long Beach, one of the most important green turtle nesting beaches on Ascension Island (7°57′ S, 14°22′ W), was patrolled on foot to locate females ashore nesting. When nesting turtles were found, they were allowed to complete egg laying and nest covering, before being placed individually into large wooden crates. A satellite transmitter (Telonics ST-6, Mesa, AZ) was then attached to the carapace with quick setting epoxy resin (figure 1). Turtles were then loaded onto a large merchant ship (the *MV Ascension*) and moved either 50 km northwest (downwind) of Ascension Island or 50 km southeast (upwind) before being released.

Six nesting turtles were located on the night of 20/21 January and then moved by ship and released on 21 January 2002, three being released northwest and three southeast; i.e. the period of confinement was kept to a minimum for all turtles and so is unlikely to have influenced the results. Throughout their period of confinement, the turtles were kept shaded and regularly had water poured over their whole body surface to ensure that they stayed cool. After release, the movements of the turtles were relayed via the Argos satellite tracking system (http://www.argosinc.com/). The Argos system assigns locations with a level of accuracy. Tracks were reconstructed using all good quality locations (location classes 1–3) and poor quality locations (location classes A, B and 0) if two such locations were obtained within 2 h and 10 km of one another.

Wind direction at Ascension Island was obtained from the island's meteorological station, which routinely logged the mean daily wind direction and the daily range of directions.

3. RESULTS

There was a marked difference in the ability of turtles to home to Ascension Island depending on their release location. Briefly, turtles released downwind quickly found their way back to Ascension Island, while those moved upwind had far more trouble relocating the island. While there was some variation in the exact routes they followed, after 4 days all three turtles displaced downwind had returned to Ascension Island (returning within 1, 2 and 4 days, respectively). By contrast, none of the three turtles displaced upwind had returned within this time (figure 2). One of the southeast-released turtles had still failed to locate Ascension Island after 59 days of tracking when transmissions ceased, but by this time this turtle appeared to be heading back to Brazil. Interestingly, this turtle had approached to within 26 km of the south of the island

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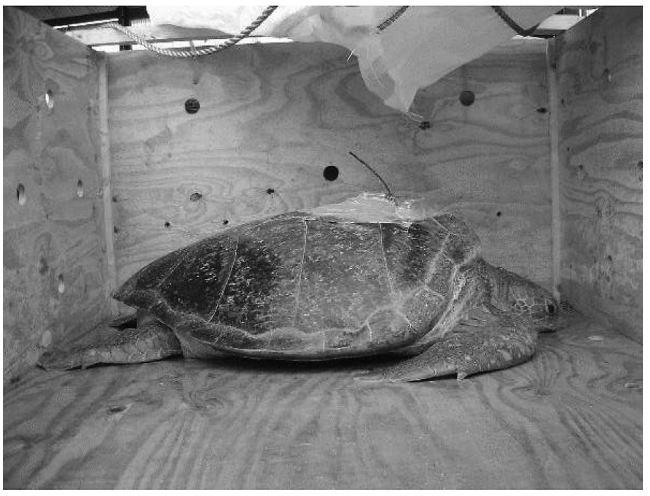

Figure 1. A green turtle (*Chelonia mydas*) during displacement equipped with a satellite transmitter on the carapace.

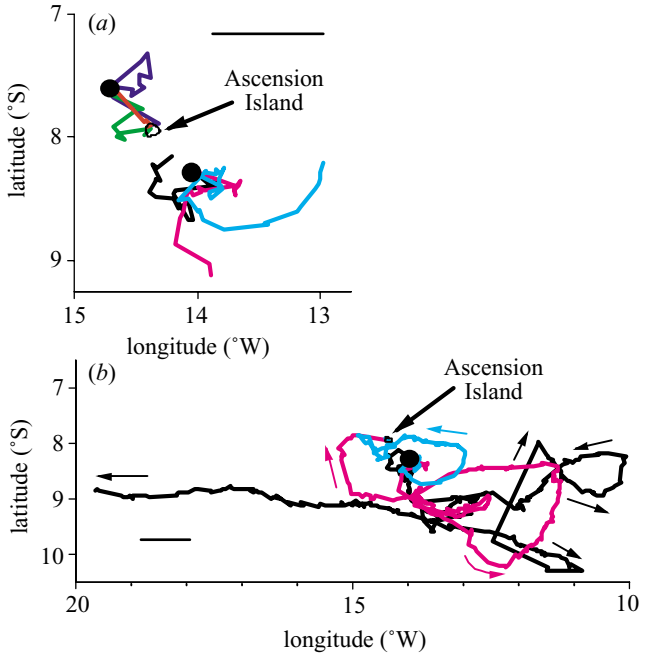

Figure 2. (*a*) Between 21 and 26 January 2002 the tracks of three turtles displaced by ship northwest (downwind) of Ascension Island and three turtles displaced southeast (upwind). After 4 days, all three turtles displaced downwind had returned to Ascension Island, but none of the three turtles displaced upwind had returned. Black circles show release points and arrows show direction of travel. (*b*) The complete tracks of the three turtles displaced upwind. One of these turtles (black line) had still failed to locate Ascension Island after 59 days of tracking (when transmissions ceased). Scale bars, 100 km. The differently coloured lines represent the different turtles' tracks.

5 days after release, but failed to find the island from that position. A second turtle released upwind only returned to Ascension Island after 27 days, while the third took 10 days to return. This last turtle passed within 13 km of the southeastern tip of Ascension Island 7 days after release, but did not return to the island until 3 days later.

Between 21 January and 28 February 2002 (when we were tracking turtles), the mean wind direction recorded at Ascension Island was 135°, with the range of mean daily directions being only 120–155°.

4. DISCUSSION

The ability of green turtles to find their way from their foraging grounds on the Brazilian coast to their nesting beaches at Ascension Island is a classic example of long-distance animal navigation. Tracking turtles the entire distance from Brazil back to Ascension Island would be a logical approach to shed light on their long-range navigational abilities. However, so far this approach has proved too logistically challenging, not least because of the following: (i) the turtles that nest at Ascension Island will not come ashore naturally on the Brazilian coast and hence are hard to locate; (ii) green turtles typically return to Ascension Island with a 3 or 4 year periodicity (Mortimer & Carr 1987) and hence even if transmitters are attached in Brazil, females may not return to Ascension Island before the batteries expire or transmitters are damaged or dislodged; (iii) the Brazilian foraging ground is home to adult green turtles from several large western Atlantic nesting populations in addition to those from Ascension Island (Pritchard 1976). Displacement experiments offer a more attainable solution for investigating how Ascension Island is located, at least from relatively short distances.

The nesting season for green turtles at Ascension Island runs from December to July, with most (more than 75%) nesting occurring in February, March and April (Godley *et al.* 2001). Individual green turtles lay several clutches within a single season (Mortimer & Carr 1987). Consequently, by conducting the displacement experiments at the start of the nesting season it is probable that each turtle was completing one of its first clutches of the season and so would have a strong motivation to return to the island to re-nest. This strong motivation appears evident by the fact that none of the displaced turtles returned directly back to Brazil, in accord with previous displacement experiments conducted at this time of year (Luschi *et al.* 2001). Therefore, the poor island-finding ability exhibited by some turtles is likely to represent a navigational inadequacy, rather than a lack of motivation. By contrast, during displacement experiments conducted later in the nesting season (April), turtles often returned directly to Brazil suggesting less motivation to try and return to Ascension Island at that time of year (Luschi *et al.* 2001).

Our results show that the release location of turtles in the oceanic waters around Ascension Island had profound implications for their ability to find their way back to the island. These results are consistent with previous ones, which demonstrated that green turtles found it difficult to locate their target even from greater distances and only moved directly to Ascension Island when downwind (Luschi *et al.* 2001). While the navigational indecision of these turtles in this previous experiment might have been attributed to magnetic disturbance from the transmitter applied on the head, such an effect is excluded in the present experiments, since transmitters were attached to the carapace (figure 1). Discussion of the potential role of magnetic maps in animal navigation continues to receive high-profile discussion (Alerstam 2003). However, while

evidence for the role of magnetic cues in animal navigation remains limited to a few cases (Phillips 1996; Fischer *et al.* 2001; Boles & Lohmann 2003), our results suggest that another mechanism is important in fine and mesoscale location of Ascension Island.

The implication of our results is that Ascension Island is located using sensory information emanating from the island itself. The nature of the orientation information that is carried downwind from Ascension Island remains unknown, but might be olfactory (turtles have an acute sense of smell; Koch *et al.* 1969) or auditory (e.g. infrasound). Briefly, during the final stages of their approach to Ascension Island, green turtles seem to orientate using wind-borne information, although the variation in approach routes from downwind merits further investigation. The present results only offer a partial solution to the problem of the navigational mechanisms used by turtles from Ascension Island to pinpoint the island while migrating from Brazil. Even if they routinely use wind-borne information perceptible for several tens of kilometres northwest of the island for the final approach to the target, it remains unknown how they manage to reach this area.

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