Where leatherback turtles meet fisheries

Conservation efforts should focus on hot spots frequented by these ancient reptiles.

The dramatic worldwide decline in populations of the leatherback turtle (*Dermochelys coriacea*)[1] is largely due to the high mortality associated with their interaction with fisheries[2], so a reduction of this overlap is critical to their survival. The discovery of narrow migration corridors used by the leatherbacks in the Pacific Ocean[3] raised the possibility of protecting the turtles by restricting fishing in these key areas. Here we use satellite tracking to show that there is no equivalent of these corridors in the North Atlantic Ocean, because the turtles disperse actively over the whole area. But we are able to identify a few 'hot spots' where leatherbacks meet fisheries and where conservation efforts should be focused.

J.-Y. Georges

Figure 1 A leatherback turtle leaving the beach of Awala-Yalimapo in French Guiana. Atlantic beaches around this area are considered to be the last major nesting sites for the species.

The Atlantic beaches of French Guiana and Suriname (5° 5′ N, 54° W) host the last major nesting sites for leatherback turtles[1] (Fig. 1). But because the oceanic migration routes of these animals are largely unknown, the development of spatially focused conservation strategies is hindered. We deployed Argos satellite transmitters on leatherback turtles nesting in French Guiana ($n=29$ turtles) and Suriname ($n=3$; turtles H, J and K) and monitored their movements during ($n=20$ individuals) and after ($n=12$) nesting seasons from 1999 to 2002.

Migration trajectories (Fig. 2) indicate that, unlike in the Pacific[3], leatherbacks disperse widely throughout the North Atlantic Ocean. They follow at least two main patterns, which depend on the year: some disperse north, broadly towards the Gulf Stream area, and others disperse to the east and remain in tropical waters.

Turtles migrating north (turtles E, F, G and H in Fig. 2) swam with strikingly constant individual headings (range: 7.1 ± 4.2° to 348.3 ± 4.0°). As they did so, they cut across the whole subtropical gyre, generally moving at an angle across the main current. After crossing the Gulf Stream, two individuals (E and G) veered to the east into the plankton-rich transition zone between the subtropical and the subpolar gyres. Their behaviour then changed markedly and became closely correlated with the local oceanographic conditions as their trajectories curved along the oceanic fronts, which are perfectly recorded in the contemporaneous satellite altimeter data. (For movie, see supplementary information.)

The turtles that were following oceanic fronts travelled more slowly than when they were moving straight towards the north (for example, turtle G: 0.57 ± 0.03 m s^{-1}, $n=183$, where n is the number of speeds calculated between locations, as opposed to 0.68 ± 0.04 m s^{-1}, $n=135$; *t*-test, $t=2.239$ and $P=0.026$). This suggests that turtles slow down to forage along productive fronts where their main prey, gelatinous plankton, is concentrated[4]. This is also where pelagic, longline fishing boats aggregate[5,6] and take a number of sea-turtles as bycatch[7].

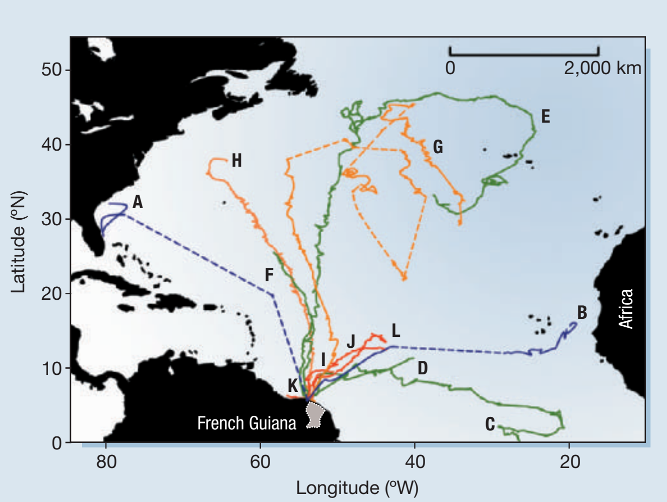

Figure 2 Reconstructed movements of 12 leatherback turtles (A–L) nesting in French Guiana and Suriname in 1999 (blue), 2000 (green), 2001(orange) and 2002 (red). Dotted lines correspond to segments containing uncertain locations because of low transmission frequency. The leatherback turtles dispersed widely throughout the North Atlantic Ocean but mostly followed two dispersion patterns, which depended on the year: four headed north to the Gulf Stream area, where they started to move in a clockwise direction, following the general ocean circulation; six others headed east, swimming mostly against the North Equatorial Current.

Other individuals (B, C, D, I, J and L) swam a short northward leg up to about 10° N and then headed generally eastwards (range: 52.5 ± 5.4° to 101.9 ± 14.4°), mostly swimming against the westward flowing North Equatorial Current. Two of them (B and C) were tracked far to the east. Turtle B reached the Cape Verde Islands before transmission stopped. Turtle C followed a southern route, crossing the eastward flowing North Equatorial Countercurrent (roughly between 10° N and 3° N) before reaching the westward flowing South Equatorial Current, where she reversed her course, heading west with the current when she reached about 2° N. This turtle probably fed on the productive frontal areas associated with the equatorial current systems. Large fishing fleets operate here, targeting tropical tuna species (*Katsuwonus pelamis*, *Thunnus obesus* and *Thunnus albacares*)[8].

During nesting, tracking data indicate that turtles remain within 20 km of the front of the Maroni river estuary — an area that is heavily exploited by French Guiana and Suriname fishing fleets catching the brown shrimp *Penaeus subtilis* and the red snapper *Lutjanus purpureus*[9]. Unsurprisingly, frequent accidental sea-turtle catches are reported for these fleets[10].

The few hot spots where turtles are likely to encounter coastal or pelagic fishing fleets are very different and are widely scattered across the Atlantic basin. This finding highlights the pressing need to develop locally adapted, but basin-wide and internationally coordinated, conservation strategies for preserving the last large population of leatherback turtles.

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Endangered species

Pan-Atlantic leatherback turtle movements

The overall extent of habitat use by leatherback turtles in the North Atlantic, and hence their possible interactions with longline fisheries, is unknown. Here we use long-term satellite telemetry to reveal that leatherbacks range throughout the North Atlantic, indicating that closing limited areas to longline fisheries will probably have only partial success in reducing turtle bycatch. Although turtles dive very deeply on occasion (one descended to a maximum depth of 1,230 metres, which represents the deepest dive ever recorded for a reptile), they generally restrict their diving to less than 250 metres, which increases the chance that they will encounter longline hooks.

Leatherback turtles (*Dermochelys coriacea*) are critically endangered (www.redlist.org), and their incidental capture by pelagic fisheries is a major source of mortality[1]. The Atlantic is the last stronghold for leatherback turtles. Longline fishermen from the United States are mandatorily excluded from a large region of the western North Atlantic (the Northeast Distant reporting area), although other countries continue to operate there[2]. An estimated 1.4 million hooks are deployed daily throughout the rest of the Atlantic[3], an intensity of fishing that has had devastating effects on a variety of apex predators[4]. As well as trying to reduce the bycatch of leatherback turtles by using different fishing methods[2], it is important to track their movements to identify areas that are at high risk from fisheries.

Leatherbacks routinely travel long distances and are found in the North Atlantic, far from their tropical and subtropical nesting beaches[5]. This has been shown by long-term tracking of individuals in the Pacific and Indian Oceans[6,7] as well as by preliminary studies in the Atlantic[8]. We used satellite telemetry to record both the horizontal and vertical (diving) movements of leatherback turtles in the North Atlantic for up to one year (for methods, see supplementary information).

We found that turtles travelled extensively throughout the Atlantic, although individuals differed in the pattern of their movements (Fig. 1a). The two turtles tracked from the Caribbean in 2002 travelled mainly eastwards: one traversed the Atlantic to within 600 km of the west African coast before returning westwards (turtle A); the other reached an area about 1,000 km from the coast of South America and remained there for several months (turtle B). Turtles leaving the Caribbean in 2003 travelled to more northerly latitudes: two travelled northwest, arriving within a few hundred kilometres of Cape Cod and Nova Scotia before turning southwards (turtles C and D, respectively); the other five travelled northeast, reaching northerly latitudes between the Azores and the United Kingdom, when some turned south (turtles E, F, G, H and I). Six of the nine tracked turtles entered the Northeast Distant area and travelled extensively inside it.

The reasons for these broad individual differences in travel routes are unknown. Ocean currents seem to play little part in driving broad-scale movements, with turtles swimming against, across and with the major current systems in the North Atlantic. Periodic residence in specific areas is probably linked to locally enhanced prey availability, as both leatherbacks and other pelagic-feeding turtle species target frontal features and mesoscale eddies[6,9].

Normally, more than half an individual's time was spent diving to depths below 10 m (data obtained from 3,304 individual 6-hour periods; mean percentage of time spent diving in each 6-hour period, 59.0%, s.d. = 27.6). Dives were generally within the epipelagic (near-surface) zone and over 99% of all dives were shallower than 250 m (Fig. 1b). This pattern of epipelagic diving was maintained throughout the tracking of each individual. Turtles occasionally dived very deeply and we recorded a maximum dive depth of 1,230 m. However, very deep dives were sporadic and extremely rare (of 16,767 dive profiles, 55 dives reached a maximum depth of over 400 m, 15 reached over 600 m and 6 reached over 800 m).

Our results have important implications for conservation techniques. Although closing specific areas to fishermen will help to reduce the leatherback turtle bycatch, the wide-ranging movement of individuals means that future conservation measures need to operate across the basin to the ensure survival of the species. Leatherbacks sometimes dive deeply at their nesting areas[10] and deep diving should reduce their interaction with fishing gear, but our long-term telemetry results indicate that they spend most of their time diving in the epipelagic zone — which is exactly the depth-range targeted by longline fishermen[11].

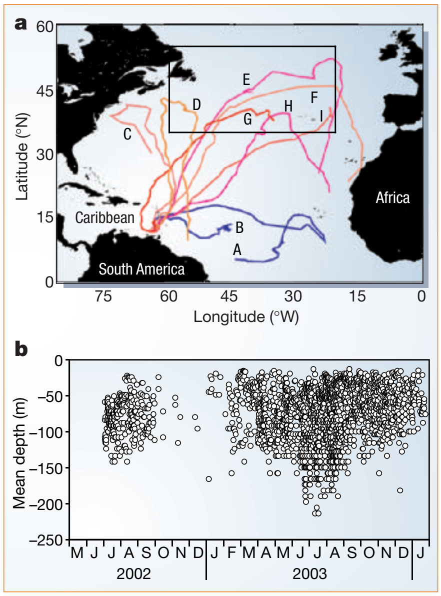

Figure 1 Movements and diving behaviour of nine leatherback turtles tracked after nesting in the Caribbean. **a,** Tracks of turtles A–I: A and B were tracked for 12 months from July 2002 until July 2003; turtles C–I were tracked for 6–8 months from May–July 2003 until January 2004. Black box outlines the Northeast Distant area, which is closed at present to longline fishing by the United States. **b,** Mean depth of dives during individual 6-hour periods, recorded from all nine turtles. For clarity, we include only those 6-hour periods during which at least 50% of the time was spent diving to over 10 metres (2,227 out of 3,304). Months indicated by initials.

Pan-oceanic movements and shallow diving are doubly disadvantageous, in that they both increase the interaction of leatherback turtles with longline fisheries. It is therefore crucial that new methodology and fishery management procedures be applied to reduce leatherback turtle bycatch.

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Animation of Turtle E displacements in relation to sea-level anomalies (SLA). SLA are based on combined altimetric measurements from the TOPEX-POSEIDON and ERS-2 satellites and mapped on a 10-day basis. The highly energetic Gulf Stream system is visible between roughly 38° N and 42° N. It features pronounced positive (red) and negative (blue/purple) SLA, corresponding to warm and cold-core eddies, respectively. This animation clearly shows that, while in the Gulf Stream area, Turtle E tends to follow fronts, specially those bordering warm-core eddies. This is where their main prey concentrate, but also where industrial pelagic fishing fleets operate.