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Tracking leatherback turtles (*Dermochelys coriacea*) during consecutive inter-nesting intervals: Further support for direct transmitter attachment

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ABSTRACT

Over recent years there have been substantial efforts to record and interpret the post-nesting movements of leatherback turtles (*Dermochelys coriacea*) breeding in tropical regions. Less well documented are the movements undertaken by individual turtles during the breeding season itself, or more specifically between sequential nesting events. Such movements are of interest for two reasons: (1) gravid female leatherbacks may range extensively into the territorial waters and nesting beaches of neighbouring countries, raising questions for conservationists and population ecologists; and (2) the magnitude of movements themselves help elucidate underlying reproductive strategies (e.g. whether to rest near to the nesting or forage extensively). Here, satellite relay data loggers are used (SRDLs) to detail the movements and behaviour of two female leatherback turtles throughout three consecutive inter-nesting intervals in the Commonwealth of Dominica, West Indies. Both near-shore residence and extensive inter-nesting movements were recorded, contrasting previous studies, with movements away from the nesting beach increasing towards the end of the nesting season. Using this behavioural study as a backdrop, the suitability of attaching satellite transmitters directly to the carapace was additionally explored as an alternative approach to conventional harness deployments. Specifically, the principal aims were to (1) gather empirical data on speed of travel and (2) assess dive performance (aerobic dive limit) to enable comparisons with turtles previously fitted with harnesses elsewhere in the Caribbean ($n=6$ turtles; Grenada, WI). This produced mixed results with animals bearing directly attached transmitters travelling significantly faster (55.21 km day^{-1}; SD 6.68) than harnessed individuals (39.80 km day^{-1}; SD 6.19); whilst no discernable difference in dive performance could be found between the two groups of study animals.

1. Introduction

Over recent decades biotelemetry has become one of the axioms of marine vertebrate ecology. However, prior to the deployment of any tracking equipment, it is imperative that researchers are aware of, and understand, the possible effects that transmitter presence and attachment procedures may have on the behaviour and physiology of the target species (e.g. Wilson et al., 1986; Bannasch et al., 1994; Thorstad et al., 2000). Moreover, the utility of tracking devices attached to free living animals depends on the extent to which these compromise the animal's well being over immediate and/or protracted time-scales (Wilson and Liebsch, 2003). Consequently, there has been a drive towards the miniaturisation of devices and continual review of the methodologies employed to attach them (Wilson et al., 1997; Thorstad et al., 2000; Watson and Granger, 1998; Godley et al., 2008).

For leatherback turtles (*Dermochelys coriacea*) the effects of different transmitter attachment techniques were recently assessed by Fossette et al. (2008). This study compared the diving behaviour and swimming efficiency of turtles with transmitters attached via harnesses and by direct attachment to the carapace. Quite strikingly the authors revealed that the turtles equipped with directly attached transmitters travelled significantly quicker throughout post-nesting migration and remained longer at given depths during dives. For a species travelling thousands of kilometres each year (Ferraroli et al., 2004; James et al., 2005; Sale et al., 2006; Eckert, 2006; Doyle et al., 2007a) and feeding on an energetically poor diet of gelatinous zooplankton (e.g., Brongersma, 1972; Davenport, 1998; Houghton et al., 2006) the ecological implications of these results are self evident. Additionally, as the manufacturing and application of harnesses is time consuming and expensive, further evaluation of this direct attachment technique might also benefit the researchers themselves (Sherrill-Mix and James, 2007). Yet for many sea turtle biologists the issue of direct attachment remains contentious when weighed against

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the more appealing alternative of using a soft, well constructed harness. Indeed the reliability of harness attachments has been the single most important factor in recording the long-term movements of leatherback turtles over the past three decades, providing ecologists and policy makers with unrivalled data to help address dramatic population declines (e.g. Ferraroli et al., 2004; Hays et al., 2004a,b; James et al., 2006; Eckert, 2006; Georges et al., 2007). Nonetheless, as ecologists we are both scientifically and ethically obliged to explore new technologies when empirical data suggest they bring about an improvement to an animal's welfare, and provide a truer representation of its innate behaviour (Godley et al., 2008). To these aims further trials of the direct attachment method were conducted under the over-arching goal of recording consecutive inter-nesting movements by leatherback turtles throughout the Caribbean. This subject is highly topical following the meta-analysis of leatherback inter-nesting behaviour which revealed that breeding leatherback turtles sometimes perform extended movements (100 s km) throughout the wider Caribbean and West Africa and may even nest in neighbouring countries (Georges et al., 2007). Further data are required as satellite transmitters are rarely used to record movements within the breeding season given problems of reconstructing tracks from often imprecise satellite locations and the risk of transmitter damage during mating events. Satellite relay data loggers (SRDLs) were used to record both movement and behaviour thus provided not only location, but an array of environmental and diving data as well (e.g. Bennett et al., 2001; Sparling and Fedak, 2004; Biuw et al., 2007). These devices have previously been used to record post-nesting migrations (Hays et al., 2004a,b) and serendipitous inter-nesting movements (Hays et al., 2004a; Georges et al., 2007), within the Caribbean providing a solid baseline for this study. More importantly, these previous deployments were made using conventional harnesses systems thereby enabling a further comparison of how different attachment techniques affect the swimming and diving performance of these critically endangered ocean migrants.

2. Methods

2.1. Transmitter deployment

Inter-nesting behaviour and post-nesting migrations of leatherback turtles were determined using Satellite Relay Data Loggers (SRDLs) (Sea Mammal Research Unit, University of St Andrews, Fyfe, Scotland, UK). SRDLs were deployed to two females on Rosalie beach, Dominica, West Indies (15°17′44N, 61°14.29W) on 10th May 2007. Each turtle had previously been tagged with standard metal flipper tags which revealed that both individuals were on their 3rd recorded nest that season at the time of deployment. A direct attachment method was used whereby 4 small holes (7 mm diameter) were drilled through the central keel of the carapace to allow plastic cable ties to be passed through. The carapace (and particularly the holes) was disinfected with Betadine® (Viatris Pharma) before and after drilling. As with previous deployments (Doyle et al., 2007b) there was no visible sign of discomfort during drilling, i.e. the animal did not react or flinch in any way. The SRDL itself had previously been glued with epoxy resin (Foilfast, SFS components, Cheltenham, UK) to an aluminium base-plate (University College Cork) (Fig. 1), the underside of which was supported by two hollow rubber tubes to avoid compression at depth and abrasion to the carapace through direct contact with the base-plate itself. The tubes and base-plate were then covered with marine grade rubber sheeting for streamlining, with the whole assemblage coated with antifouling paint (CSC Micron Extra, International Paints) (Fig. 1). The combined transmitter and base-plate was finally attached to the turtle by passing four cable ties through holes in the base-plate and carapace, with two of the ties tightened fully whilst the other two were left slightly loose to allow for carapace expansion during post-nesting migrations. This technique has been previously detailed by Doyle et al. (2007a) off the west coast of Ireland and is based on the method of direct attachment reported by Fossette et al. (2008).

2.2. Reconstructing inter-nesting movements

SRDLs were located with the Argos system (http://www.argosinc.com). Each Argos location is provided with a measure of its accuracy, called the location class. Location classes A, B and 0 are the least accurate, and classes 1, 2 and 3 are the most accurate having nominal standard deviations around the true position of 150 m, 350 m and 1000 m respectively. The accuracy of class A locations is close to that of class 1, whilst classes B and 0 are the least accurate (Hays et al., 2001). To assess turtle movements within the Caribbean locations were filtered, including all class 1, 2 and 3 locations plus and other locations that were within 10 km of the previous or successive location. Two mean positions for each turtle were then calculated for each day (i.e. the first mean position was calculated from the first 50% of locations received that day). Visual analysis of these mean daily location versus the noisier scatter of all locations, confirmed in each case that the details of each turtle's movement had been successfully captured. Using these data, the magnitude of movements was compared with previous published incidental tracking data from Grenada (West Indies), French Guiana and Gabon (Georges et al., 2007).

2.3. Inter-nesting dive behaviour

In addition to relaying individual dive profiles, SRDLs also summarise dive information into 6-hour summary periods (see Hays et al., 2004a for full details). Included in the parameters determined for each summary period were the following: percentage of time spent shallower than 10 m; percentage of time spent deeper than 10 m; mean depth of dives less than 10 m; mean depth of dives to over 10 m; mean dive duration for dives to over 10 m; and maximum depth. Each SRDL also relayed diagnostic data concerning the total number of transmissions that had been made, the performance of the saltwater switch that was used to synchronise transmissions with surfacing events and the maximum depth attained.

Summary periods were initially given in Greenwich Mean Time (GMT) to represent four daily periods: 00:00–06:00, 06:00–12:00, 12:00–18:00, and 18:00–00:00. These periods were converted to local time (GMT − 4 h) resulting in the following 6-hour summary periods: 02:00–08:00, 08:00–14:00, 14:00–20:00, and 20:00–02:00. Respectively these were termed periods 1–4. In previous studies (e.g. Eckert et al., 1989a; Hays et al., 2004a; Southwood et al., 2005) distinct diel patterns have been elucidated for post-nesting leatherback turtles, with more time spent diving deeper during the night. Although there is little evidence for leatherback turtles feeding during the breeding season (Wallace et al., 2005) it is possible that this diel behaviour represents an extension of typical open-water foraging behaviour whereby turtles dive more extensively at night in an attempt to locate nocturnally ascending gelatinous zooplankton (Eckert et al., 1989a; Myers and Hays, 2006). Consequently, the diel patterns within inter-nesting behaviour were assessed not as a measure of feeding activity or success but as a proxy of foraging effort (i.e. repetitive nighttime diving suggests that the turtles were not merely resting to conserve energy reserves). To investigate both diel changes in behaviour and changes between sequential inter-nesting suitable proxies were therefore needed. This was achieved by dividing each inter-nesting interval (and subsequent post-nesting migration) into the 4 daily 6-hour summary periods. From these data we calculated (1) mean % time spent diving and (2) mean depth for each period (e.g. the mean % time spend diving during period 1 throughout the 1st inter-nesting interval).

2.4. Post-nesting migration and speed of travel

Post-nesting migration was reconstructed for both turtles (termed D1 and D2) only using location classes 1–3. Rate of travel during post-nesting migrations was calculated from the time the turtles left Dominica following their last nesting event based on 'distance from home' (i.e.