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Habitat use and diving behaviour of gravid olive ridley sea turtles under riverine conditions in French Guiana

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ABSTRACT

The identification of the inter-nesting habitat used by gravid sea turtles has become a crucial factor in their protection. Their aggregation in large groups of individuals during the inter-nesting period exposes them to increased threats to their survival - particularly along the French Guiana shield, where intense legal and illegal fisheries occur. Among the three sea turtle species nesting in French Guiana, the olive ridley appears to have the most generalist diet, showing strong behavioural plasticity according to the environment encountered. The large amounts of sediments that are continuously discharged by the Amazon River create a very unusual habitat for olive ridleys, i.e. turbid waters with low salinity. This study assesses the behavioural adjustments of 20 adult female olive ridleys under such riverine conditions. Individuals were tracked by satellite from Remire-Montjoly rookery in French Guiana using tags that recorded the location and diving parameters of individuals, as well as the immediate environment of the turtles including the in situ temperature and salinity. Data concerning potential preys was provided via collection of epifauna by a trawler. Multiple behavioural shifts were observed in both horizontal and vertical dimensions. During the first half of the inter-nesting season, the turtles moved away from the nesting beach (21.9 ± 24.7 km), performing deeper (12.6 ± 7.4 m) and longer (29.7 ± 21.0 min) dives than during the second half of the period (7.4 ± 7.8 km, 10.4 ± 4.9 m and 25.9 ± 19.3 min). Olive ridleys remained in waters that were warm (range: 26–33 °C) and which fluctuated in terms of salinity (range: 19.5–36.4 psu), in a relatively small estuarine habitat covering 423 km^2. If olive ridleys were foraging during this period, the potential preys that might be available were mostly crustaceans (43%) and fish (39%), as expected for the diet of this generalist species during this period. This study highlights the numerous behavioural adaptations of this species in response to the unusual riverine conditions of the French Guiana continental shelf.

1. Introduction

The tracking of highly mobile organisms through satellite telemetry helps to identify key breeding and foraging areas that play a crucial role in species conservation (Stokes et al., 2015). Given the high inter-individual plasticity of these migrant organisms, long-term monitoring is usually required to delineate adequate protected areas based on species distribution (Schofield et al., 2010). A better understanding of how animals interact with their environment is therefore needed to implement efficient conservation measures, especially when dealing with threatened species such as sea turtles.

The use of satellite tracking to study sea turtles movements and their habitat use during the breeding-nesting season highlighted strong site fidelity for both males and females (Schofield et al., 2010; Hays et al., 2014; Chambault et al., 2016b). The identification of such habitat is of major importance due to the large aggregation of individuals close to the nesting beaches during this period. Additionally, such periods make sea turtles particularly vulnerable due to the high energy costs of the reproduction and the nesting activities. An evaluation of the home range is an essential tool to establish a picture of the core activity areas for the protection of such endangered species (Scott et al., 2012; Schofield et al., 2013; Pendoley et al., 2014). This tool has been widely used to support conservation initiatives for leatherback (Witt et al., 2008), kemp ridley (Seney and Landry, 2008), loggerhead (Schofield et al., 2010; Hart et al., 2010), green (Richardson et al., 2013; Hart et al., 2013; Blanco et al., 2013), hawksbill turtles (Marcovaldi et al., 2012; Hart et al., 2012; Revuelta et al., 2015) and olive ridleys (Maxwell et al., 2011).

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During the inter-nesting season, olive ridley sea turtles show a strong behavioural plasticity in their dispersal and diving behaviour (Hamel et al., 2008; Maxwell et al., 2011; Pikesley et al., 2013). According to the geographic area and therefore the resources available, olive ridleys can adopt either a capital breeding strategy, in which they store fat reserves at their foraging grounds and then cease to feed during the breeding-nesting season (Drent and Daan, 1980), or use an income breeding strategy, whereby they continue to feed throughout the reproduction period (Miller, 1997; Colman et al., 2014).

The olive ridley is distributed across all tropical and subtropical waters, and appears to be the most abundant sea turtle species (Godfrey and Godley, 2008). This species has been studied in the Pacific (Polovina et al., 2004; Swimmer et al., 2006, 2009; Plotkin, 2010), the Arafura Sea off Northern Australia (Whiting et al., 2007; McMahon et al., 2007; Hamel et al., 2008; Pikesley et al., 2013), and in the Indian (Rees et al., 2012) and Atlantic Oceans (Reis et al., 2010; Maxwell et al., 2011). In the western part of the Equatorial Atlantic, French Guiana hosts one of the largest population of olive ridleys (Kelle et al., 2009; The State of the World's Sea Turtles, 2016). This olive ridley population has already been tracked during post-nesting migration (Plot et al., 2015; Chambault et al., 2016a), but only one study to date has focused on the movements and diving behaviour of this species during the inter-nesting season, highlighting the surprising reproductive synchrony of olive ridleys nesting in French Guiana (Plot et al., 2012).

The Guianese continental shelf is strongly enriched by the large amounts of sediments and suspended materials that are continuously discharged by the Amazon River (Milliman and Meade, 1983; DeMaster et al., 1996), creating turbid and warm waters that fluctuate drastically in terms of salinity between the dry and the rainy season. Given the active behaviour adopted by this population during the post-nesting migration (Chambault et al., 2016a) and the inter-nesting season (Plot et al., 2012), and in view of the abundance of potential prey for olive ridleys over the French Guiana shield (Guéguen, 2000), we hypothesize that gravid females nesting in French Guiana will dive consistently, adjusting their behaviour to the fluctuating conditions encountered on the Guianese continental shelf.

To assess olive ridley behavioural shifts in response to estuarine conditions, twenty adult females were equipped with satellite tags on Remire-Montjoly beaches (French Guiana) in 2013 and 2014. The tags recorded the behaviour (location and diving parameters) of animals and sampled the in situ temperature and salinity of their immediate environment. Combined with the details of available prey collected in trawl nets, the information supplied by these tags will help to characterize (1) the displacements and (2) the diving behaviour of this vulnerable species in this unusual habitat during the energetically costly inter-nesting season.

2. Methods

2.1. Ethics statements

This study meets the legal requirements of the countries where this work was carried out, and follows all institutional guidelines. The protocol was approved by the "Conseil National de la Protection de la Nature" (CNPN, http://www.conservation-nature.fr/acteurs2.php?id=11), the French Ministry for Ecology, Sustainable Development and Energy (permit Number: 09/618) acting as an ethics committee in French Guiana. After the evaluation of the project by the CNPN, fieldwork was carried out in strict accordance with the recommendations of the Police Prefecture of French Guiana, Cayenne, France, in order to minimize the disturbance of animals.

2.2. Study site and animal tagging

During the inter-nesting seasons in 2013 and 2014, 20 adult female olive ridleys were fitted with satellite tags on Remire-Montjoly beaches (4.53°N, −52.16°W, Cayenne, French Guiana). From 26/06/13 to 29/06/13, 8 Argos-linked Fastloc GPS tags (MK10, Wildlife Computers Redmond, WA, USA) and 2 Conductivity Temperature Depth Fluorometer-Satellite Relayed Data Loggers (CTD-SRDL, Sea Mammal Research Unit, University of St. Andrews, Scotland) were deployed. From 25/06/14 and 30/07/2014, 10 additional CTD-SRDL tags were fitted on olive ridleys. The attachment procedure followed the standard methods described in Baudouin et al. (2015).

2.3. Data collection

2.3.1. Nocturnal patrols

Nesting events were identified using direct observation during nocturnal surveys rather than evidence of haul-outs from tracking data. This choice is explained by the lack of precise resolution from the Argos (>1500 m) and GPS locations (<100 m) and the potential inaccuracy of the GEBCO database in such coastal habitat, making the identification of nesting events unreliable if based on tracking data alone. Daily nocturnal patrols were therefore performed from April to September in 2013 and 2014 on Remire-Montjoly and Cayenne beaches to observe the entire nesting season of olive ridley turtles. Using the same procedure as that described in Chambault et al. (2016a), each observed female was scanned with a TROVAN Reader to identify a Passive Integrated Transponder (PIT) and if the individual was not tagged, a PIT was inserted in the top right triceps muscle. To complete these nocturnal patrols, daily counts of female's traces on the beach were conducted each day to ensure that no nesting event was missed.

2.3.2. Argos-linked Fastloc GPS tags

The procedure to extract the inter-nesting route data was identical to that used in Baudouin et al. (2015). The Argos-linked Fastloc GPS tags recorded Argos locations and GPS positions at 4-hour intervals (<1% of the locations transmitted). These tags also provided diving data, i.e. maximum dive depths, dive durations and in situ temperature data, binned as 4-hour period histograms. Maximum depths were collected in different bins, every 10 m from 10 to 100 m, then every 50 m from 100 to 250 m. Maximum dive durations were stored from 30 s to 1 min, then every minute from 1 to 5 min, and finally every 10 min from 10 to 60 min. In situ temperatures were recorded during dives from 20 to 32 °C, every one degree Celsius.

2.3.3. CTD-SRDL tags

The CTD-SRDL tags provided the locations of animals via Argos data and recorded simplified profiles of the diving parameters (dive depth, time at depth, dive duration and post-dive surface interval) and oceanographic data in the form of vertical temperature and salinity profiles taken during the ascent phase of turtle dives (Boehme et al., 2009). The CTD-SRDL tags were programmed to send summarized dive profiles using the compression algorithm described by Fedak et al. (2001), providing four depth records for each dive (instead of the single maximum depth per dive provided by Argos-linked Fastloc GPS tags). Temperature and salinity data were quality controlled using the procedure described in Roquet et al. (2011), with an estimated accuracy of 0.02 °C in temperature and 0.05 psu in salinity.

2.3.4. Prey abundance from trawler

Over the French Guiana continental shelf, 31 samples of potential olive ridley prey (epifauna) were collected during a survey carried out by IFREMER using a bottom trawler between 15/11 and 20/11/2014. The fauna was sampled with a shrimp trawl (1 m vertical opening, 6.7 m horizontal opening, 45 mm cod-end mesh size). The trawl hauls were performed on the seafloor at depths of 10 to 60 m. All the individuals collected at each location were identified and counted. As it was not possible to identify the specific species of some individuals, we classified the preys into five groups: cephalopods, crustaceans, cnidarians, molluscs and osteichthyes (fishes).