



Satellite-tracked movements of female *Dermochelys coriacea* from southeastern Brazil

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ABSTRACT: Four female leatherback sea turtles *Dermochelys coriacea* were satellite tracked from the southeastern coast of Brazil (3 from nesting beaches in the state of Espírito Santo, and 1 recovered from a driftnet off the coast of the state of São Paulo), representing the first study of movements of leatherbacks nesting on Brazilian grounds. The results suggest that during the internesting period, leatherbacks may disperse up to 160 km from the nesting beach using an area of 4400 km². Tracking also revealed shared feeding areas in southern South America, comprising Brazilian, Uruguayan, and Argentinean waters, and highlighted important interactions with fisheries along nesting, migratory, and feeding habitats. The presence in migratory/foraging areas of turtles from at least 2 different nesting populations from both sides of the South Atlantic Ocean supports the concept that management efforts for this species must incorporate a broad regional perspective.

KEY WORDS: *Dermochelys coriacea* · Satellite telemetry · Migration · Internesting · Postnesting · Atlantic Ocean

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INTRODUCTION

Leatherback turtle *Dermochelys coriacea* nesting sites are spread over tropical and subtropical areas along all ocean basins (Spotila et al. 1996, Eckert 2006, Eckert et al. 2006, Thomé et al. 2007, Benson et al. 2007a, Fossette et al. 2008). Their pelagic habits, reinforced by several satellite telemetry studies, evidence a very broad distribution, reaching temperate and even sub-polar areas (Eckert 2006, James et al. 2006a,b). Extensive migratory movements have been reported in the North Atlantic (Hays et al. 2004, James et al. 2005a,b, Eckert 2006, Eckert et al. 2006),

eastern Pacific (Morreale et al. 1996, Spotila et al. 2000, Shillinger et al. 2008), western Pacific (Benson et al. 2007b), and Indian Oceans (Hughes et al. 1998, Luschi et al. 2003).

However, the conservation status of different populations varies: in the eastern Pacific Ocean, populations face strong declines, probably due to high rates of incidental captures in fisheries (Eckert & Sarti 1997, Spotila et al. 2000, Martínez et al. 2007, Santidrián Tomillo et al. 2007) and poor foraging habitats (Saba et al. 2007, 2008). In contrast, the largest rookeries in the world are located in the Atlantic (Eckert 2006, Fretey et al. 2007, Girondot et al. 2007, Hilter-

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man & Goverse 2007, Fossette et al. 2008), and stable or increasing trends have been reported (Dutton et al. 2005, Chacón-Chaverri & Eckert 2007, Ordoñez et al. 2007), even in severely reduced nesting populations (Thomé et al. 2007).

Defining high-use habitat areas or pathways can help to understand the differences in the conservation status of different populations and guide the development of effective conservation efforts. In the South Atlantic, however, information regarding habitat use and migratory movements of leatherbacks is restricted to a few tag recoveries (Billes et al. 2006), a single study of foraging leatherbacks captured at sea (López-Mendilaharsu et al. 2009), and recent studies of postnesting movements from Gabon (Fossette et al. 2010, Witt et al. 2011). These studies documented transoceanic movements from nesting grounds in Africa to South America, and seasonal latitudinal movements of foraging leatherbacks between temperate and tropical high-use areas in South America. Particularly lacking is a study of leatherbacks from southwest Atlantic nesting beaches.

The nesting ground on the north coast of the state of Espírito Santo, southeastern Brazil (around 19° S), comprises the only known regularly used leatherback nesting site in Brazil (Fig. 1). The number of nests laid each year varies between 6 and 92 along a 160 km section of the coastline, with more than 90% of the nests located along the southernmost 80 km (Thomé et al. 2007). To manage this nesting area, the entire coastline is divided into 1 km patrol zones,

numbered south to north; in the southern 37 km, the area is protected under an Indigenous Land (km 1–23) and a Federal Conservation Unit (Reserva Biológica de Comboios, REBIO Comboios, km 23–37). The remaining area is mostly occupied by farming interspersed with a few villages located along the coast (Pontal do Ipiranga, km 92; Guriri, km 145; and Itaúnas, km 159). The coastline and beaches are relatively well preserved with minimal development pressures.

This study aimed to understand for the first time the internesting and postnesting movements of females tracked from an endangered and severely depleted rookery located in Brazil.

MATERIALS AND METHODS

Projeto TAMAR-ICMBio, the Brazilian Sea Turtle Conservation Program, has been working on the northern coast of the state of Espírito Santo since 1982, initially at Comboios and later gradually extending its activities northward. Since 1991, between 1 October and 31 January the entire leatherback nesting area has been patrolled daily at dawn by local fishermen, as well as by technical staff to record and protect nests, and during the peak of the season at night to tag nesting turtles (Almeida & Mendes 2007, Thomé et al. 2007).

Satellite transmitters (KiwiSat 101, Sirtrack) were attached to 3 nesting leatherback females during the 2005–2006 nesting season. One additional female

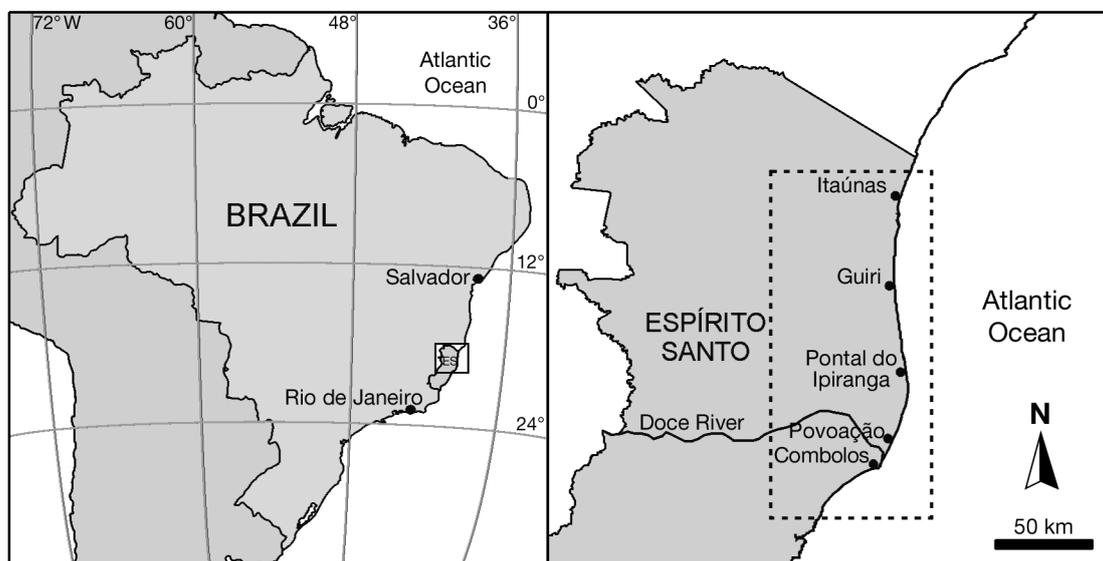


Fig. 1. *Dermochelys coriacea*. Nesting area in the state of Espírito Santo (ES) in southeastern Brazil (dashed rectangle)

was satellite tagged on 12 February 2006 (also during the nesting season) after capture in a driftnet, ca. 200 km off the coast of the state of São Paulo (24° 59' S, 44° 31' W) (Table 1).

Transmitters were powered by 4 C-size lithium batteries (0.5 W output), and were configured to transmit continuously upon surfacing during the first 30 d of deployment, and 24 h on/48 h off after this period. Transmissions, processed via Argos (<http://argosinc.com>), reported location information, surface temperature at the time of transmission, battery voltage, and number and duration of transmissions. Each transmitter was attached to a flexible harness using standard methods that have been used in many previous leatherback satellite tracking studies (e.g. Eckert et al. 1989, 2006, James et al. 2005a,b, Eckert 2006, Benson et al. 2007b, Hitipeuw et al. 2007, Shillinger et al. 2010).

Each turtle was measured with flexible plastic tapes (curved carapace length and width) and tagged with inconel tags (National Band and Tag Co.) in both rear flippers. Other data, such as date, time, and location, were also collected.

We located turtles through the Argos system with geolocations being categorized into 7 location classes (3, 2, 1, 0, A, B, and Z). Location classes (LCs) 3, 2, and 1 are categorized to lie within 150 m, 150–350 m, or 350–1000 m, respectively, of the tag's true position, while LCs 0, A, and B have no location error estimate. Location data provided by Argos were downloaded and analyzed in the Satellite Tracking and Analysis Tool (STAT; Coyne & Godley 2005), including data on bathymetry associated with the turtles' positions. Routes were reconstructed using LC 1–3 positions and filtered Argos positions LC 0 and A based on a maximum rate of travel of 5 km h⁻¹. Geographic information systems software (ArcGis 9.1, ESRI) was used to map turtle movements and calculate high-use areas. To define important habitats for each turtle, we calculated fixed kernel home ranges using Hawth's Analysis Tools for ArcGIS

(Beyer 2004). High-use areas were defined using 50% utilization distribution (UD) of kernel home range estimation (KHRE; Eckert et al. 2006). To reduce temporal autocorrelation and sampling bias, data sets were filtered using the best single location per day, and the internesting period data were assessed separately from postnesting period data. Additional information from direct observations recorded during beach patrolling was used to complement information regarding internesting behavior.

RESULTS

Transmitters were attached to 3 females in Linhares, northern Espírito Santo (Table 1), on 13 to 15 December, during the peak of the nesting season. The nesters (Dc1–3) were tracked for 26, 388, and 409 d, respectively. A fourth leatherback female (Dc4) was tagged around 200 km off the southeastern Brazilian coast and was tracked for 97 d (Table 1). This turtle (Dc4) received the transmitter recovered from Dc1, who had been killed earlier in a coastal gillnet.

Interesting movements

The 3 females tagged at Espírito Santo nesting beaches returned to nest at least once after transmitter deployment (Table 2). The fourth female (Dc4) was tagged at sea and did not nest while being tracked.

No patterns were evident among movements between individual consecutive nesting attempts, except that all turtles re-nested along different sections of the coast at each nesting (Fig. 2, Table 2).

After satellite tag deployment, Dc1 (Fig. 2A) traveled in a loop ca. 150 km offshore and returned to nest 13 d after deployment. This turtle then moved

Table 1. *Dermochelys coriacea*. Deployment and tracking information for leatherback turtles equipped with satellite transmitters at nesting beaches in Espírito Santo and off the coast of São Paulo, Brazil, from December 2005 to January 2007. CCL: curved carapace length. Dates given in dd/mm/yy

Turtle ID	Turtle tags	CCL (cm)	Deployment location	Deployment date	Date of last location	Days tracked	Minimum distance traveled (km)	End battery voltage (mA)
Dc1	BR 48825/ 48833	156	Pontal do Ipiranga	13/12/05	08/01/06	26	1868	62
Dc2	BR 48540/ 48544	155	Comboios	15/12/05	05/01/07	388	15982	40
Dc3	BR 48549/48550	153	Comboios	15/12/05	28/01/07	409	12698	35
Dc4	BR 49147/49148	153	Off São Paulo	12/02/06	20/05/06	97	4165	18

Table 2. *Dermochelys coriacea*. Nesting activity information recorded for the 3 leatherbacks tagged in December 2005 at the nesting beaches in the state of Espírito Santo, Brazil. Deployment dates (as dd/mm/yy) are in **bold**; time intervals are in days. (–) indicates first record of an individual in the season

Turtle	Nesting date	Record location (beach zone)	Distance from last landings (km)	Record type	Interval between consecutive records	Interval between 1st and last records	Maximum spatial interval between nests (km)
Dc1	11/11/05	46	–	Nest	–	57	66
	13/12/05	96	50	Nest	32		
	26/12/05	31	65	Nest	13		
	07/01/06	30	1	False nest	12		
Dc2	04/11/05	33	–	Nest	–	53	46
	15/12/05	24	9	Nest	41		
	27/12/05 ^a	70	46	Nest	12		
Dc3	05/11/05	25	–	Nest	–	73	36
	25/11/05	31	6	Nest	20		
	05/12/05	27	4	Nest	10		
	15/12/05	28	1	Nest	10		
	27/12/05	61	33	Nest	12		
	06/01/06 ^a	40	21	Nest	10		
	17/01/06	42	1	Nest	11		

^aFemales not found in the field; nests attributed to tagged females from telemetry data

south, in a new loop that reached ca. 80 km offshore and emerged 12 d later in a false attempt to nest. On the next day (8 January), the turtle died entangled in a coastal gillnet in the mouth of the Doce River, 26 d after deployment. The turtle was entangled by the front flipper, and apparently the harness did not contribute to the entanglement. Necropsy revealed eggs, indicating that further nesting activity could have been possible. Data from beach patrols and observed internesting intervals suggested that this turtle had nested 5 times (Table 2) before entanglement. Dc1's in-water latitudinal internesting movements far exceeded the limits of the nesting area, comprising more than 300 km. The total distance traveled was 1281 km during the internesting period, and the maximum distance from the coast was 161.6 km. The high-use area comprised 4443 km² (50% KHRE).

Dc2 (Fig. 2B) moved ca. 56 km offshore, then headed south close to the municipality of Anchieta, and thereafter turned northward, looping very close to the coast. At the latitude of the Doce River mouth, the turtle headed west, meandering in a loop over 10 to 20 km from the shoreline, and then moved southward, heading to the coast around the southern limit of the nesting area; from this point, the turtle moved northward, navigating very close to the shoreline, for ca. 90 km, emerging to the last nest on 27 December, 46 km away from its first nest site. The total distance traveled was 724.3 km during the internesting period,

and the maximum distance from the coast was 71.7 km. The high-use area comprised 2667 km² (50% KHRE).

Turtle Dc3, which received the transmitter on the same day as Dc2, showed more coastal movements (Fig. 2C), reaching ca. 50 km from the coast. Despite some meandering movements at the northern limit of the nesting area, this turtle stayed mostly in the southern nesting area and nested 3 times after deployment. Beach patrol data closely agree with the telemetry data and show that the turtle laid nests over a 73 d timeframe in the southern region. Nests were distributed as far as 36 km apart (Table 2). The total distance traveled was 1038.7 km during the internesting period, and the maximum distance from the coast was 53.1 km. The high-use area comprised 438.5 km² (50% KHRE).

Movements of female leatherbacks ranged from 40 to 118 km d⁻¹ (mean) between nesting events. All turtles reached the shelf break, and the movements of Dc1 ranged along the 2000 m isobath (Fig. 2A). The total area, as delineated by the 75% UD, was centered at the Doce River and extended offshore 60 km and 150 km to either side of the nesting area, comprising 4941 km². The high-use area as described by the 50% UD was also centered at the Doce River mouth, and extended over a 50 km radius offshore and to each side along the coast, comprising 1170 km² (Fig. 3). The overall 25% UD corresponded to 356.5 km².

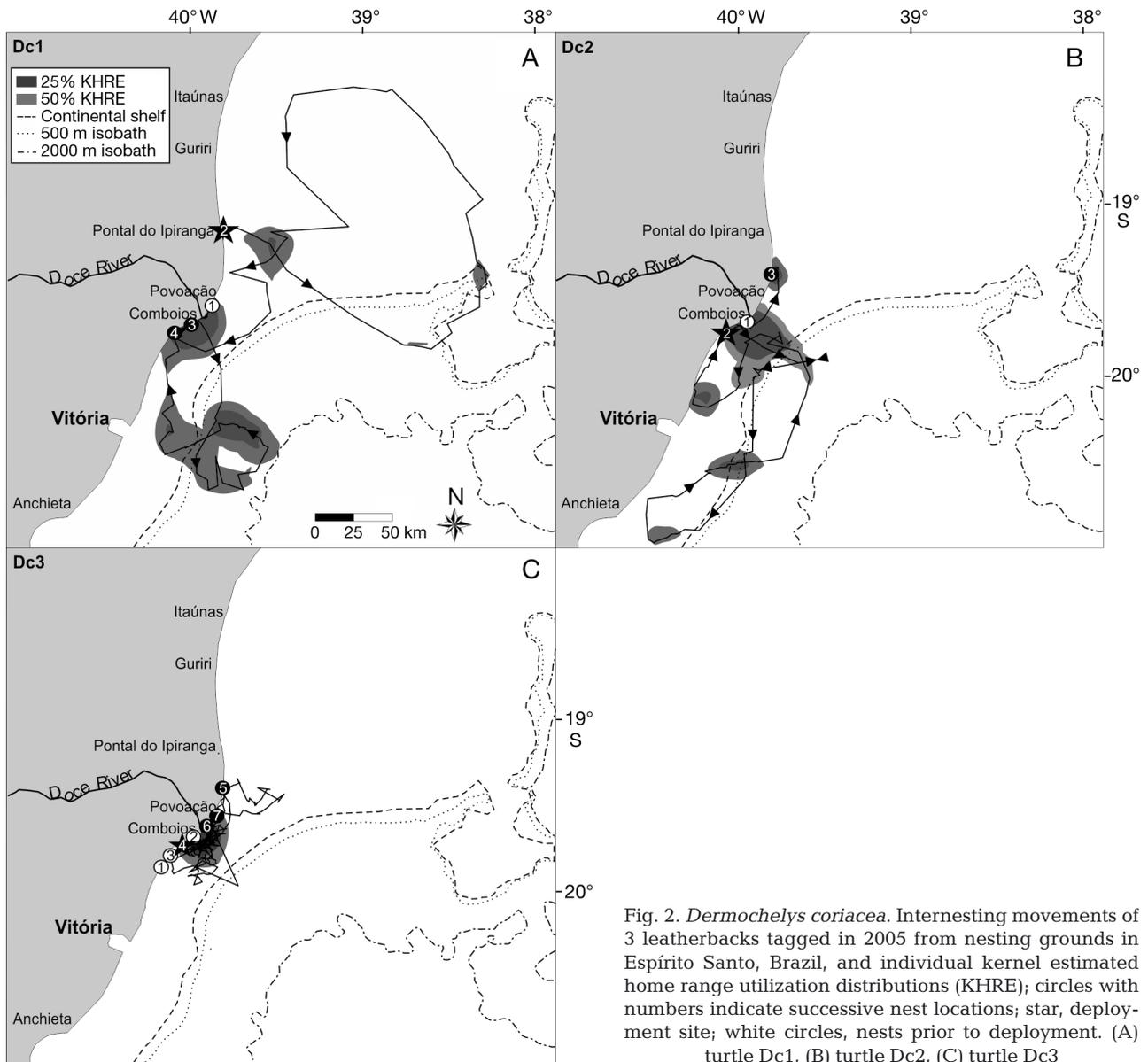


Fig. 2. *Dermochelys coriacea*. Interesting movements of 3 leatherbacks tagged in 2005 from nesting grounds in Espírito Santo, Brazil, and individual kernel estimated home range utilization distributions (KHRE); circles with numbers indicate successive nest locations; star, deployment site; white circles, nests prior to deployment. (A) turtle Dc1, (B) turtle Dc2, (C) turtle Dc3

Postnesting movements

At the end of the nesting season, Dc2 and Dc3 started their migration southward. Dc2 moved offshore to oceanic waters before turning west and traveling 57 d to the coast of the State of Rio Grande do Sul; the turtle arrived on 23 February 2006 and remained for 50 d. After that, Dc2 moved south to waters off Uruguay, arriving on 15 April and spent 15 d there before moving northward to the state of São Paulo, which she reached on 3 June. The turtle then moved east on a 6775 km transoceanic journey that lasted 216 d, and reached waters 350 km off the coast of Angola, when transmissions ceased (Fig. 4A).

Dc3 moved south along the continental shelf over a period of 72 d, reaching the Rio de la Plata estuary, between Uruguay and Argentina, on 31 March 2006. After 55 d of residence in the estuary, the turtle moved northward for 93 d (starting on 25 May) towards the coast off the state of São Paulo (26 August). Following a 151 d gap in satellite transmissions, locations were again reported from the La Plata estuary on 26 January 2007 (Fig. 4B). These final transmissions lasted only 3 d.

Dc4, tagged after capture in the driftnet fishery on 12 February 2006, moved eastward to oceanic waters 600 km from the coast, and then moved northward, reaching the coast of the state of Rio de Janeiro on 21