Satellite tracking highlights difficulties in the design of effective protected areas for leatherback turtles during the internesting period

Running header: Satellite tracking leatherback turtles

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Abstract

The leatherback turtle (*Dermochelys coriacea*) is a globally distributed species and is subject to fisheries bycatch throughout its range. Protection from fisheries within pelagic foraging habitats is difficult to achieve but may be more tractable when populations are concentrated near neritic breeding and nesting grounds. We used satellite telemetry to describe patterns of habitat utilisation during the internesting period for leatherback turtles (n = 7) nesting at Mayumba National Park in Gabon on the equatorial West African coast (South Atlantic). The National Park includes critical nesting grounds and a Marine Protected Area (MPA) to 15 km offshore. Turtles dispersed widely from the nesting beach spending 62 ± 26% of tracking time outside of the protected confines of the National Park. This propensity to disperse is likely to increase the chance of deleterious interactions with fisheries in the region. Patterns of habitat utilisation indicate the need for wider spatial scale planning on the West African continental shelf to enhance protection of leatherback turtles while seasonally occupying these habitats in great numbers for breeding and nesting.

Keywords

Breeding, *Dermochelys coriacea*, fisheries bycatch, fisheries exclusion zone, Marine Protected Areas, marine spatial planning, nesting

The use of Marine Protected Areas (MPAs) to safeguard high-seas habitats of marine vertebrates (Hyrenbach et al. 2000) has been largely unrealised, despite the mandates of several multilateral agreements (e.g. United Nations Convention on the Law of the Sea, Convention on Biological Diversity and the Convention on Migratory Species). Marine vertebrates therefore remain at risk from fisheries while occupying the pelagic realm (Hall et al. 2000, Lewison et al. 2004, Carranza et al. 2006). In contrast, coastal MPAs may be more successful in protecting species of conservation concern as surveillance and enforcement become tractable. MPAs could provide an important management tool for migratory species, such as the leatherback turtle (*Dermochelys coriacea*), that occupy neritic habitats for breeding and nesting.

Leatherback turtles exhibit the widest spatial distribution of all marine turtles (Plotkin 2003) moving through pelagic habitats undertaking foraging migrations for gelatinous prey (James et al. 2005b). Reproductively active adults converge on natal tropical and subtropical coastal habitats to breed and nest (Miller 1997). Leatherback turtles nesting in Gabon (Fig. 1a) form a globally important sub-population (Fretey 1984, Formia et al. 2003, Sounguet et al. 2004). Three centres of nesting occur on the Gabonese coast (Fig. 1a) at Pongara, Gamba and at Mayumba National Park (Sounguet et al. 2004, Verhage et al. 2006). Given knowledge regarding the reproductive patterns of this species (James et al. 2005a), it is likely that the coastal waters of Gabon host substantial numbers of leatherback turtles for several months each year (September to March).

An MPA was established at Mayumba (Fig. 1b, ~ 900 km^2) in 2002 as part of a larger effort to protect habitats and species across Gabon (www.gabonnationalparks.com). The park is a fisheries exclusion zone encompassing a 15 km band of neritic habitat and a 1 km band of adjacent land stretching northwards for 60 km from Gabon's southern border with the Republic of the Congo and its Conkouati-Douli National Park (Fig. 1b). Mayumba National Park was designated to protect marine turtles (i.e. leatherback turtles and the olive ridley turtle, *Lepidochelys olivacea*) and humpback whales (*Megaptera novaeangliae*) that seasonal visit its waters.

Leatherback turtles are reported to disperse widely from focal points of nesting (Eckert et al. 1989, Keinath & Musick 1993, Eckert 2006); this behaviour that complicates the assessment of the anthropogenic risks in Gabonese coastal waters (e.g. industrial trawl fisheries). We therefore deployed platform terminal transmitters (PTTs – Kiwisat 101, n = 4 and Satellite Relayed Data Loggers - SRDLs, n = 3) communicating with Service Argos (www.argos-system.org) to record the at-sea distribution of leatherback turtles (Table 1) nesting at Mayumba National Park.

Movements of tracked individuals were reconstructed from Argos location estimates assigned error classes 3, 2, 1, 0 and A using the Satellite Tracking and Analysis Tool (Coyne & Godley 2005). Classes 3 to 0 have decreasing location accuracy from <150 m to >1000 m; class A has no location error estimate (see Hays et al. (2001) for a review of Argos tracking with respect to marine turtles). To remove spatially inaccurate location estimates each movement track was independently filtered using the minimum redundant distance and distance, angle and rate filters of the Douglas Argos-Filter algorithm (www.alsaka.usgs.gov). Argos location estimates with error classes 2 and 3 were always retained. Prior to analysis all movement tracks were resampled at 1 hour intervals assuming straight-line movement between location estimates. All distance measurements were made using straight-line principles.

The location of PTT attachment sites were recorded using a hand-held GPS receiver. We derived the locations of subsequent nesting events from Argos location estimates using a set of assessment criteria, these were a) directed movement towards the coast, b) an increase in location estimate class, which commonly occurs with nesting and c) haul-out information (periods of non-submergence greater than 10 minutes) for individuals tracked using SRDLs. These criteria were required to logically intersect no earlier 8-9 days following PTT attachment or subsequent nesting. This duration typifies the re-nesting interval of leatherback turtles (Miller 1997).

During their internesting periods, 10 ± 1 days (mean ± SD) - range 8 to 13 days, leatherback turtles ranged widely moving a mean minimum straight-line distance of 249 ± 101 km. This pattern of movement is consistent with studies on internesting leatherback turtles from the North Atlantic (Eckert et al. 1989, Keinath & Musick 1993). Tracked individuals occupied 7670 km^2 of neritic habitat (Fig. 2), estimated using the □-hull technique where □ = 7, (Burgman & Fox 2003) and remained exclusively on the continental shelf (coastline to 200 m depth contour). Turtles B, D and E moved into the waters of the Conkouati-Douli National Park within Congolese Territorial Waters (Fig. 2) for 46 ± 13 % of their respective tracking durations.

Leatherback turtles spent 62 ± 26 % - range 16 % to 100 % of internesting time outside of Mayumba National Park; in these habitats they remain at risk of incidental capture by licensed and unlicensed industrial trawl fisheries (Billes et al. 2003, Sounguet et al. In Press). The most frequented region of the internesting habitat occurred within and on the periphery of Mayumba National Park (Fig. 1c). This pattern most likely highlights the shuttling movements made by females to and from the nesting beach every ~10 days. The mean time to depart the national park following nesting was 1 ± 0.7 days; most protection is therefore conferred by the National Park in the hours prior to and following nesting.

The spatial extents of the National Park encompassed 9 % of habitat utilised by tracked individuals (Fig. 2). This disparity between available protected habitat and that which would offer enhanced protection (e.g. 50% or 75% of internesting habitat), demonstrates the difficulties in demarcating coastal MPAs. Restricting access to resource rich coastal waters (e.g. fisheries and oil) poses considerable problems for governments that are required to balance economic growth with the need to protect species of conservation concern.

Mayumba National Park is nested within several existing marine zones (Fig. 2) but historically little capacity has existed to monitor and subsequently enforce them. In previous years adult leatherback turtles have been washed ashore dead on the beaches of the National Park and at Gamba, 160 km to the north, coincidentally observed with fisheries violations (Verhage et al. 2006). Rates of strandings are unlikely to represent the extent of deleterious interactions occurring at sea, particularly as prevailing currents (Fig. 1b) most likely wash severely injured or dead leatherback turtles away from the coast. Limited satellite tracking suggests that these areas are likely to be densely occupied (Fig. 1c).

Nest site fidelity varied appreciably 13.1 ± 10.6 km (mean ± SD) – range 1.2 to 28.3 km and beach activity was not restricted to the National Park – turtle E was observed in the Conkouati-Douli National Park approximately 30 km south of the PTT attachment site. Monitoring of nesting undertaken at Mayumba National Park and at the Gamba rookery, shows that some exchange of individuals occurs on an annual basis (Verhage et al. 2006). This demonstrates that the wide ranging movement patterns of internesting leatherback turtles are matched in geographic scale by changes in nest site selection. This plasticity highlights the additional challenges of limiting illegal egg harvest and the complexities of ensuring consistent protection across geopolitical zones both on land and at sea.

The Memorandum of Understanding (MoU) for West African turtles introduced by the Convention on Migratory Species encourages signatories, such as Gabon and the Republic of Congo, to protect marine turtles through mitigating potential risks. An important step towards the MoU would be the implementation of marine spatial planning with a goal to optimally select regions requiring protection for leatherback turtles. This process may be informed by the use of distribution data recorded by satellite telemetry. Practically, enhanced protection may be achieved through the use of fisheries zoning (e.g. Fig. 2), which instigates a seasonal fisheries closure between October and March in habitats surrounding Mayumba and the marine region of Conkouati-Douli National Park (~1260 km^2). This recommended zone would offer an additional ~4100 km^2 of protection. The recent commissioning of a fishing vessel monitoring system and the proposed introduction of Turtle Excluder Devices in Gabon may also make a substantial contribution to mitigating fisheries risk. Taking an integrative approach would however require bilateral agreements to ensure consistent and uniform fisheries surveillance between both countries. Despite these obstacles, such an approach, especially when operated in tandem with appropriate control of pelagic fisheries, is likely to yield beneficial results for leatherback turtle population growth and overall ecosystem health.

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Biographical sketches

Matthew Witt is a graduate student with the Marine Turtle Research Group at the University of Exeter, UK. His research centres on the use of spatial ecology to aid an understanding of marine vertebrate distribution and foraging ecology. **Annette Broderick** and **Brendan Godley** coordinate the Marine Turtle Research Group at a range of sites around the world including Ascension Island, Northern Cyprus and the UK Overseas Territories. **Michael Coyne** coordinates the work of www.seaturtle.org. **Angela Formia** works extensively in the field of marine turtle conservation genetics in West Africa and coordinates the Marine Turtle Partnership in Gabon. **Solange Ngouessono** is the Director of Mayumba National Park, and **Richard Parnell** directs the Wildlife Conservation Society's project in Mayumba. **Guy-Phillipe Sounguet** directs the activities of Aventures Sans Frontieres, a NGO concerned with habitat and species protection in Gabon.

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Table 1

Turtle	PTT Type	Curved Carapace Length (cm)	Time to first intersection of park boundary following nesting (days)	Internesting duration (days)	Distance from prior nesting site (kilometres)	Time inside park (% internesting duration)	¹Minimum distance moved during internesting period (kilometres)	¹Maximum distance from shore (kilometres)
†,◊ A	Kiwisat 101	141	0.5	10	•,□ 28.3	20 %	211	32
†,° B	Kiwisat 101	160	1.4	□ 10	•,□ 18.1	16 %	*263	65
† C	Kiwisat 101	148	1	□ 12	1.2 ± 0.35	18 %	315	34
† D	Kiwisat 101	114	-	10	3.8 ± 0.15	100 %	197	17
			0.5	8	• 5.4 ± 1	41 %	*202	35
†,◊ E	SRDL	147	0.6	▲ 13	• 24.2 ± 0.35	38 %	*453	46
‡,◊ F	SRDL	146	0.6	10	□ 10.6	28 %	96	27
			0.7	11	□ 4.9	30 %	311	44
‡,◊ G	SRDL	152	2.8	▲ 11	□ 20.9	49 %	195	34

† PTT attached using a harness system modified from Hays et al. (2004)

‡ PTT attached using a direct carapace attachment technique modified from Lutcavage et al. (1999)

◊ Post-nesting movements recorded by satellite telemetry

° PTT failed at sea on day 8 of the internesting period

□ PTT removed after nesting

▲ SRDL haul-out timer recorded periods of prolonged dryness (>10 and <45 minutes) in days prior to nesting that most likely repesent unsuccessful nesting attempts

• Nesting visually observed by third party - no GPS location coordinates available

□ Nesting location derived from Argos location estimates with error classes A and B that provide no error estimate

* Turtle entered territorial waters of the Republic of the Congo

¹ Straight-line distance

Figure 1

a) Leatherback turtle nesting sites in Gabon (filled circles) including Mayumba National Park. Labels: (I) Equatorial Guinea territorial sea and exclusive economic zone, (II) Sao Tome & Principe economic zone, (III) Gabon territorial sea, contiguous zone and exclusive economic zone and (IV) Congo territorial sea. Hatched zone represents disputed region. Dashed line polygon depicts spatial extents of Figure 1b and c. Inset map shows the African continent, box (dashed line) indicates the spatial extents of Figure 1a.

b) Argos derived tracks of turtles A-E. Dotted black lines are bathymetric contours. Solid black arrows highlight dominant offshore ocean currents derived from absolute dynamic topography satellite altimetry data.

c) Habitat utilisation by tracked turtles using a single daily position taken at 12-midday for each turtle. Vertical inset colour scale indicates the number of occupation events per cell. Dotted black lines are bathymetric contours.

Figure 2

Existing and recommended spatial zoning on the continental shelf of Gabon and the Republic of the Congo. Industrial trawlers can not operate in the existing Artisanal Fishery Zones (AFZ). In Gabon, the AFZ stretches from the coastline to 3 nautical miles, in the Republic of the Congo it reaches 6 nautical miles. Artisanal fishing is permissible inside Conkouati-Douli National Park up to 6 nautical miles from the coast but only to villages within the Park. The recommended seasonal fisheries closure (SFC) should operate between September and March end each year for industrial trawl fisheries. No fishing is permissible inside Mayumba National Park. Mayumba National Park's existing buffer zone (BZ) should act as seasonal closed zone (September to March end) for Artisanal Fishing; industrial trawlers should be excluded all year.

Figure 1

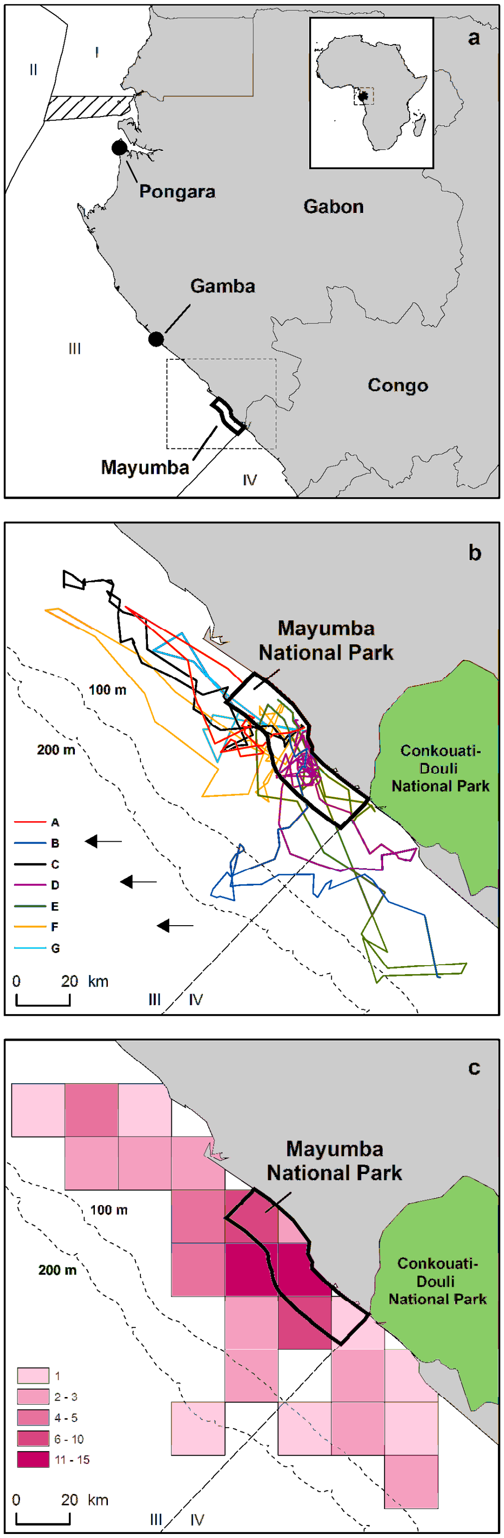
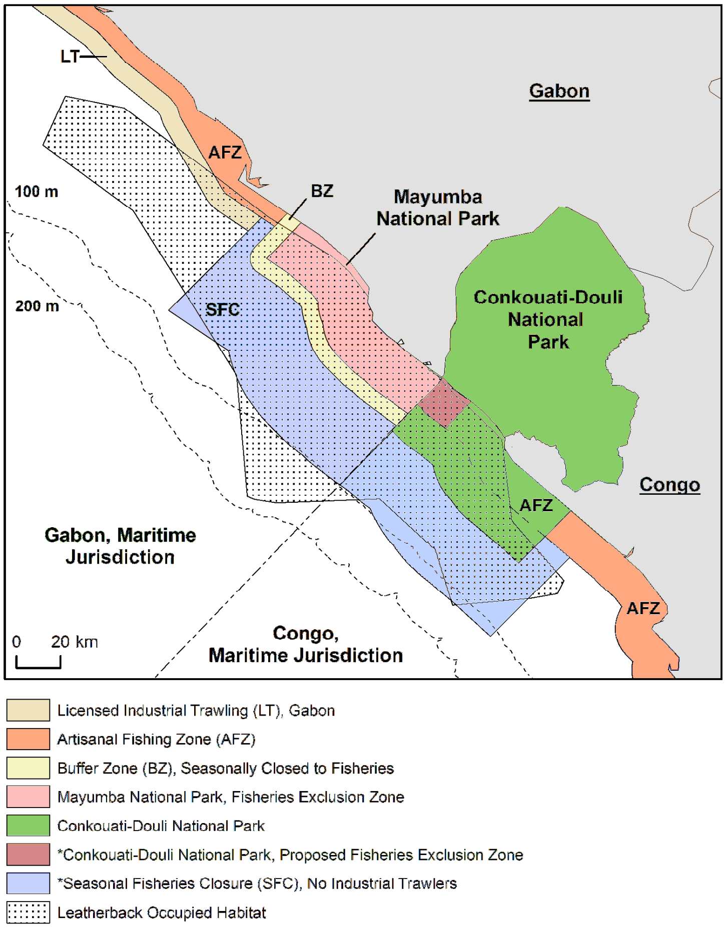

a
I
II
Pongara
Gabon
Gamba
III
Congo
Mayumba
IV
b
Mayumba
National Park
100 m
200 m
Conkouati-
Douli
National Park
A
B
C
D
E
F
G
0 20 km
III
IV
c
Mayumba
National Park
100 m
200 m
Conkouati-
Douli
National Park
1
2 - 3
4 - 5
6 - 10
11 - 15
0 20 km
III
IV

Figure 2


LT
Gabon
AFZ
100 m
BZ
Mayumba
National Park
Conkouati-Douli
National
Park
200 m
SFC
Congo
AFZ
Gabon, Maritime
Jurisdiction
AFZ
0 20 km
Congo,
Maritime Jurisdiction
Licensed Industrial Trawling (LT), Gabon
Artisanal Fishing Zone (AFZ)
Buffer Zone (BZ), Seasonally Closed to Fisheries
Mayumba National Park, Fisheries Exclusion Zone
Conkouati-Douli National Park
*Conkouati-Douli National Park, Proposed Fisheries Exclusion Zone
*Seasonal Fisheries Closure (SFC), No Industrial Trawlers
Leatherback Occupied Habitat