



## Aerial surveying of the world's largest leatherback turtle rookery: A more effective methodology for large-scale monitoring

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### ABSTRACT

For many marine megavertebrate species it is challenging to derive population estimates and knowledge on habitat use needed to inform conservation planning. For marine turtles, the logistics required to undertake comprehensive ground-based censuses, across wide spatial and temporal scales, are often insurmountable. This frequently leads to an approach where a limited number of index nesting beaches are monitored in great detail by foot. In this study we use nationwide aerial surveying interfaced with ground assessments across three seasons of leatherback turtle nesting in Gabon (Equatorial West Africa), highlighting the importance of a synoptic approach to marine turtle monitoring. These surveys allow the first complete population assessment of this nesting aggregation to be made, identifying it as the world's largest for the species (36,185–126,480 clutches, approximating to 5865–20,499 breeding females per annum and a total estimate of 15,730 to 41,373 breeding females). Our approach also serendipitously provides insights into the spatial appropriateness of Gabon's protected areas network, for example (mean  $\pm$  1SD) 79  $\pm$  6% (range 67–86%) of leatherback turtle activities recorded during aerial surveys ( $n = 8$ ) occurred within protected areas (345 km, 58%, of surveyed coastline). We identify and discuss sources of potential error in estimating total nesting effort from aerial surveying techniques and show that interannual variation in nesting is considerable, which has implications for the detection of statistically significant changes in population size. Despite its relative costliness per day, aerial surveying can play an important role in providing estimates of relative population abundance of large vertebrates dispersed over extensive areas. Furthermore, it can provide data on habitat use and deliver real-time information on the spatial efficacy of protected area networks.

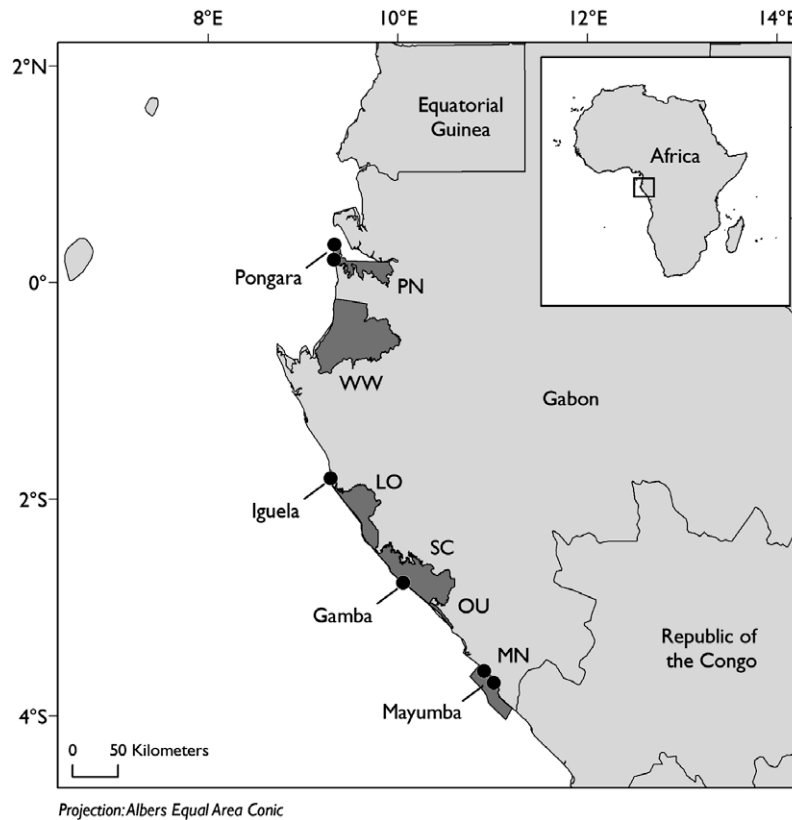
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### 1. Introduction

Deriving population estimates and gaining knowledge of habitat use has become increasingly important for marine megavertebrate species that face anthropogenic risks throughout their range (Hall et al., 2000; Lewison et al., 2004). Such data are essential for identifying changes in abundance and for developing spatially and temporally explicit management plans. Estimating the size of populations that are widely dispersed (e.g. across an ocean basin) is complex but can be made easier if species exhibit predictable migrations and/or form seasonal aggregations (e.g. albatrosses



**Fig. 1.** National Parks and Reserves (i.e. protected areas) of Gabon bordering the Atlantic Ocean. Filled circles indicate locations where ground truthing was undertaken. Labelled regions (Pongara, Gamba and Mayumba) contributed data on the daily frequency of leatherback turtle nests counted. Labels: Pongara National Park (PN), Wonga Wongue Reserve (WW), Loango National Park (LO), Sette Cama Reserve (SC), Ouangu Reserve (OU) and Mayumba National Park (MN).

(Poncet et al., 2006), seals (Thompson et al., 2005), whales (Stevick et al., 2006) and marine turtles (Broderick et al., 2006). In non-breeding years, leatherback turtles (*Dermochelys coriacea*) disperse widely over oceanic areas (Benson et al., 2007; Ferraroli et al., 2004; Hays et al., 2006; Hughes et al., 1998) but a proportion of adults seasonally aggregate near a small number of major rookeries where nesting can be enumerated as an index of population size (Spotila et al., 1996). Although this behaviour facilitates enumeration the logistics of undertaking comprehensive ground-based censuses are often insurmountable (i.e. transport, geography, personnel, safety and fiscal cost), leading to an approach where a limited number of beaches are monitored in great detail.

While population estimates of marine turtles are commonly based on ground-derived counts of nests, several studies have used aerial surveying to enumerate nesting over extensive spatial areas (Hitipeuw et al., 2007; Hopkins-Murphy et al., 2001; McGowan et al., 2008); most notably for the leatherback turtle by Pritchard (1982). Aerial surveying has also been used to enumerate turtles in foraging habitats (Houghton et al., 2006; Marsh and Saalfeld, 1989). The method provides an unparalleled approach for the swift collection of data over considerable spatial scales (many 100's km), which facilitates more meaningful and coherent estimates of population size, but also aids the understanding of nesting habitat preference and threats (Laurance et al., 2008).

For some of the most globally significant leatherback turtle nesting populations it has been possible to estimate population size, trends and patterns of habitat use (Kelle et al., 2007). For example, the Indo-Pacific population has experienced declines (Hitipeuw et al., 2007; Reina et al., 2002; Spotila et al., 2000; Tomillo et al., 2007); whereas, some nesting populations in the North Atlantic are increasing (Girondot et al., 2007; Dutton et al., 2005;

McGowan et al., 2008). In contrast, the status of other Atlantic populations is more uncertain. In the eastern South Atlantic, leatherback turtles nest on the West African coast from Mauritania to Angola (Bal et al., 2007; Fretey et al., 2007; Rader et al., 2006; Weir et al., 2007) with the largest and globally significant aggregation occurring along the coast of Gabon (Fretey, 1984; Fretey et al., 2007). The Gabon nesting aggregation contributes a significant proportion of nesting effort in the South Atlantic and is geographically and genetically distinct from the North Atlantic population (P. Dutton personal communication). Based on a ground survey of the Gabon coastline between Mayumba and Gabon's border with the Republic of the Congo (Fig. 1, approximately 90 km coastline) Billes et al. (2000, 2003) estimated 29,700 and 37,150 nesting emergences in the 1999–2000 and 2000–2001 seasons, respectively.

In this study we use aerial surveying over three nesting seasons along the coast of Gabon (600 km). Our specific aims were to: (1) ascertain the usefulness of aerial surveying as a means of counting leatherback turtle nesting activity, (2) estimate the number of clutches laid each nesting season and the numbers of females nesting each year, (3) derive a total population estimate for the Gabon rookery, (4) describe spatial patterns of nesting and (5) provide a preliminary overview of the spatial adequacy of the protected Areas network.

## 2. Materials and methods

### 2.1. Aerial surveying

Aerial surveys were conducted using light aircraft (Cessna 182 and 202) travelling at speeds of 180–190 km h<sup>-1</sup> at an altitude of

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