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## A Significant Nesting Population of Loggerhead Turtles at the Nature Reserve of Santa Luzia, Cabo Verde

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**ABSTRACT.** – Loggerhead sea turtles *Caretta caretta* are globally endangered. The population nesting in Cabo Verde is genetically distinctive and numerically important in a global context. In Cabo Verde, the majority on the nesting takes place on the island of Boavista, but recent work suggests that other important nesting sites may exist. Santa Luzia is the only large uninhabited island in Cabo Verde. In this study, beach surveys revealed 289 nests in 2011, 1817 nests in 2012, and 563 nests in 2013, which means that Santa Luzia may host more than 1% of the loggerhead nesting population in the Atlantic. The sex ratio of turtle hatchlings currently being produced on Santa Luzia is female biased, but there is still a good production of males. The results highlight the importance of the island of Santa Luzia for the conservation of loggerhead turtles, particularly considering that unlike other islands in Cabo Verde, this is a nature reserve where no beach development is taking place and where nest and female poaching is well controlled by the activities of conservation organizations, such as the nongovernmental organization Biosfera 1.

**KEY WORDS.** – Reptilia; Testudines; Cheloniidae; *Carretta caretta*; Atlantic Ocean; nesting activity; population assessment

The highly migratory loggerhead sea turtle *Caretta caretta* is the most common and the most representative sea turtle of the Cabo Verde Islands (Fretey 2001; Varo-Cruz 2010; Marco et al. 2011; Melo and Melo 2013). According to the International Union for Conservation of Nature (2012) Red List criteria, this megavertebrate is endangered, and the Cabo Verde islands represent the third most important nesting site globally and the most important site throughout Africa (Fretey 2001; Lino et al. 2010; Monzón-Argüello et al. 2010; Marco et al. 2011).

Loggerhead turtles have shown marked population declines historically and in recent years across all oceans (e.g., Kamezaki et al. 2003; Witherington et al. 2009; Casale et al. 2011). The main known threats include collection of eggs and capture of nesting females, beach development, accidental capture in fishing gear, and, potentially, global warming (Spotila 2004). In Cabo Verde, despite national laws (Article No. 40 of Decree-Law No. 53/2005) that prohibit the capture, possession, simple acquisition, landing, marketing, and consumption of sea turtles, poaching is still excessive and is thought to have caused substantial reductions in nesting numbers in the inhabited islands (Lino et al. 2010; Monzón-Argüello et al. 2010; Cozens et al. 2011; Marco et al. 2012; Diallo and Dossa 2012; Melo and Melo 2013). Fisheries bycatch, although little studied and underreported, may also present a very significant threat to this particular population (Melo and Melo 2013).

The loggerhead turtle population reproducing in Cabo Verde is genetically isolated from other populations, which implies that this is a distinctive management unit and reinforces its high conservation priority (Monzón-Argüello et al. 2010; Marco et al. 2011; Wallace et al. 2011). Research on sea turtles in Cabo Verde has traditionally been centered on the Island of Boavista (López-Jurado et al. 2000; Fretey 2001; Lino et al. 2010; Marco et al. 2011). This island supports the majority of the Cabo Verdean nesting population, but recent work at other sites is slowly revealing that other important nesting beaches exist that merit special attention for monitoring and conservation (Andrade 2008; Cozens et al. 2009, 2011; Lino et al. 2010).

Here we report on the monitoring and conservation efforts on the only uninhabited large island of Cabo Verde, Santa Luzia, and show that this protected site receives significant numbers of nesting females and has a role to play in loggerhead conservation. Data on nesting numbers, nesting success, hatching success, and sex ratios are presented.

### METHODS

Santa Luzia is located on the northwestern portion of the Cabo Verde archipelago. The island has a surface of 35 km<sup>2</sup> and, together with its neighboring smaller islands (Raso and Branco) and adjacent seas, is classified as a nature reserve. Loggerhead turtles also nest at Branco,

but for the present study, monitoring surveys were carried out only on the island of Santa Luzia (Fig. 1a).

In 2011, we regularly (almost daily) visited the 3 largest beaches of the island (Palmo Tostão, Achados, and Francisca) throughout the nesting season, with occasional visits to other (very small) beaches. Results showed that Palmo Tostão beach and other small beaches harbored only ~ 5% of the nesting (see below), and in the 2 remaining years, daily monitoring was confined to Achados (2.1 km long) and Francisca (4.6 km long) (Fig. 1b).

The beaches were monitored by foot, mapped, and georeferenced using GPS. The main nesting beaches were patrolled each morning during the nesting period of the 3 consecutive years (2011–2013; 1 July–15 October). With the aid of a GPS, coordinates were taken from all the nests, which were marked with a PVC pipe with its identification (name of surveyor, date laid, and number of the nest). Owing to some logistical difficulties, there were 15 d in total (spread between the 3 yrs) during which it was not possible to count the nests and tracks from the night before. When the count was not possible, the number of nests and tracks was estimated by linear interpolation by taking the mean of 3 d before and 3 d after the gap (never more than 3 successive gaps) (Cstry et al. 2009). Tracks were enumerated and erased following the count in order to avoid recounting them the next morning (Lino et al. 2010; Marco et al. 2012).

A hatchery with capacity to accommodate 30 nests was built on Francisca beach at lat 16°44'307"N, long 24°42'883"W (Fig. 1b), in 2012 and 2013 in order to relocate the nests that were laid in places considered unsafe (Sonmez and Ozdilek 2013).

Turtles may not always nest each time they come ashore; thus, nesting success was defined as the percentage of emergences that resulted in nesting (Cstry et al. 2009; Varo-Cruz 2010; Marco et al. 2011, 2012). No incidents of poaching are known to have taken place in the past few years in Santa Luzia. Because of that, the total numbers of nesting females for each of the 3 seasons were calculated by dividing the total number of nests laid in that season by the estimated mean number of nests laid by each female during a given season (Marco et al. 2012). Given the absence of data on this parameter for Santa Luzia, we used the value of 5, estimated elsewhere in Cabo Verde (Varo-Cruz et al. 2007; Marco et al. 2012; TAOLA, *pers. comm.*, June 2013).

Hatching success and incubation period were assessed by following 21 nests (hatchery) in 2012 and 69 nests in total (24 for Francisca, 20 for Achados, and 25 for the hatchery) in 2013. These nests were opened after laying to count the number of eggs and then covered again (Miller and Limpus 1983; Varo-Cruz 2010). This process must be completed within a limited time (maximum 10 hrs after laying) and done very carefully to avoid death induced by the movement of embryos (Limpus et al. 1979; Miller and Limpus 1983; Varo-Cruz 2010). Fifty

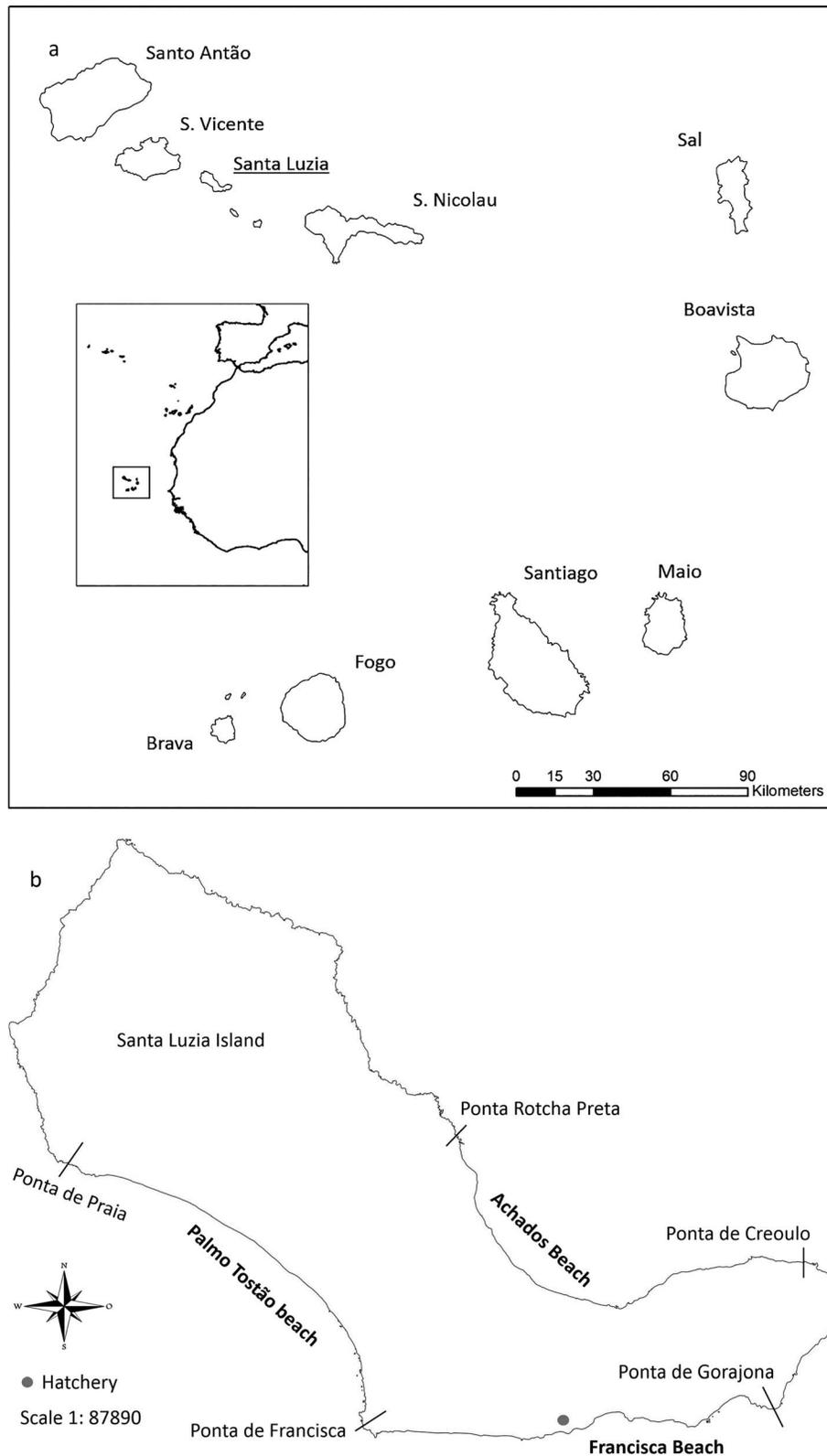
nests in total (Francisca and Achados) in 2013 were selected randomly through the length of the 2 main beaches and monitored until hatching. The incubation period of the monitored nests is defined as the time between when the nest was laid and when the hatchlings first crawl out of the nest toward the sea. Volunteers followed the nests daily until hatching evidence was noticed (hatchling tracks of baby turtles on the sand or a small concave dip bowl in the sand surface above the nest). After hatching, during the excavation of the nests monitored, the numbers of eggs that hatched and the eggs that did not hatch were counted. Hatchlings dead or alive inside the nest were counted as successfully hatched. Hatching success was obtained by dividing the number of eggs that hatched by the clutch size (including the nests with 0% of hatching).

To estimate if the Santa Luzia rookery makes a balanced contribution of both sexes to the population pool, we used 2 complementary approaches. First, we used the published relations between nest incubation times and clutch sex ratios for loggerheads (Godfrey and Mrosovsky 1997; Godley et al. 2001) to estimate the sex ratio of each monitored nest in 2013. Second, whenever possible, we collected dead hatchlings inside these nests, randomly selected 1 hatchling per nest ( $n = 26$ ), and stored it in 96% ethanol. In the laboratory, the kidney/gonad complexes were removed, embedded in resin (Technovit 7100 system), and sectioned in 3- $\mu$ m-wide slices, stained with toluidine blue. Males were identified by a thin cortex and the presence of hollow seminiferous tubes in the medullar region of the gonad, while females were identified by a thick, heavily staining cortex associated with a homogeneous medulla (for more details on this procedure, see Rebelo et al. 2012).

## RESULTS

Our study confirmed that *C. caretta* is the only species that nests in Santa Luzia. Results from daily beach surveys indicate that the monitoring campaign in Santa Luzia, which ran from 1 July to 15 October, covered almost the entire loggerhead nesting season and that most nesting activities took place in August and September (Fig. 2).

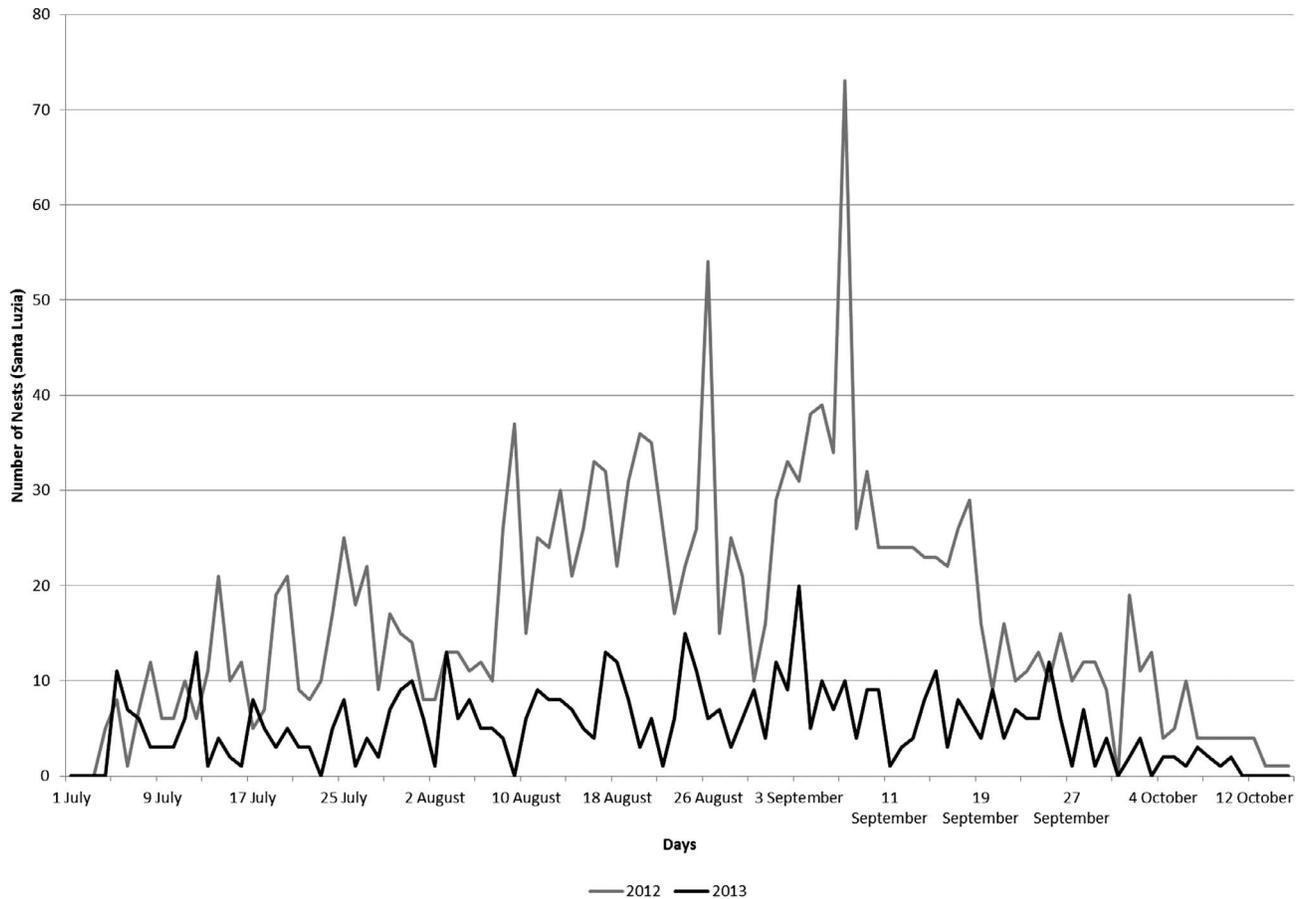
In 2011, Palmo Tostão Beach had 13 nests compared with 134 nests on Francisca Beach and 137 on Achados Beach. Because of this small number of nests, the beach of Palmo Tostão was dropped from regular monitoring in subsequent years. In total, we counted 289 nests in 2011, 1810 nests in 2012, and 555 nests in 2013 (because of gaps in coverage, 289 nests in 2011, 1817 nests in 2012, and 563 nests in 2013 were not directly observed but were estimated by linear interpolation [see “Methods”]). These values do not include the tracks for which definitive nesting could not be assigned. Nesting success was 31% for both 2012 and 2013, with a total number of 5793 emergences in 2012 and 1707 emergences in 2013



**Figure 1.** (a) Map of the Republic of Cabo Verde, western Africa, showing the location of the archipelago and all the main islands (Santa Luzia is underlined). (b) Outline of the island of Santa Luzia with details of beaches and location of the hatchery.

(Table 1). Occasional surveys on the other beaches on Santa Luzia showed only that they receive a much reduced number of nests. Assuming that each nesting female laid 5 clutches in a nesting season (Varo-Cruz et

al. 2007; Marco et al. 2012; TAOLA, *pers. comm.*, June 2013), we estimate that the total number of nesting females for each season was 57 in 2011, 363 in 2012, and 113 in 2013.



**Figure 2.** The temporal pattern of the number of nests of the 2 main beaches (Francisca and Achados) in the 2 nesting seasons 2012–2013.

Combining observations from 2012 and 2013, the mean ( $\pm$  SD) number of eggs per nest (clutch size) was  $89.8 \pm 14.1$  (range, 51–126) ( $n = 85$  nests). During the monitoring process in 2013, we had to discard 11 nests in situ (1 nest in Francisca and 5 nests in Achados) that were lost as a result of their marks being displaced. For the same year, 25 nests in the hatchery and 44 natural nests were followed from laying to hatching or to failure (natural nests included 24 nests on Francisca and 20 nests on Achados). The hatching success rate for nests monitored in the wild was  $47.6\% \pm 28.5\%$  (range, 0–90.6,  $n = 39$ ) for 2013. The hatching success rate for nests monitored in the hatchery was  $54.8\% \pm 27.2\%$  (range, 5.7–95.8,  $n = 21$ ) for 2012 and  $56.8\% \pm 26.9\%$  (range, 0.0–93.2,  $n = 25$ ) for 2013.

Incubation times in 2013 ranged from 49 to 61 d. Francisca was the nesting beach with the shortest mean incubation time ( $53 \pm 2.23$  d;  $n = 24$ ), while the highest values were registered in the hatchery ( $55.2 \pm 2.45$  d;  $n = 24$ ). Using the published relation between incubation duration and clutch sex ratios for loggerheads, we estimated that there were only small differences in the proportion of females in different beaches in 2013: Francisca ( $79.5\% \pm 5.5\%$  females;  $n = 24$ ), hatchery ( $73.1\% \pm 7.9\%$ ;  $n = 24$ ), and Achados ( $77.7\% \pm 8.1\%$ ;  $n = 20$ ). The estimated proportion of females in the entire sample of nests ( $n = 69$ ) was  $76.7\% \pm 7.6\%$ . In 14 of the 26 dead hatchlings analyzed, the gonadal tissue was undamaged enough for histological sex determination; of these, 57% ( $n = 8$ ) were female.

**Table 1.** Loggerhead sea turtle nesting success on Santa Luzia in 2012 and 2013.

Beaches	2012			2013		
	Nests	Emergences (nest + tracks)	Nesting success (%)	Nests	Emergences (nest + tracks)	Nesting success (%)
Francisca	996	3431	29.0	277	905	30.6
Achados	821	2519	32.6	286	923	31.0
Total	1817	5950	30.5	563	1828	30.8

## DISCUSSION

The present study confirmed that the Island of Santa Luzia is a significant breeding site for loggerhead turtles, with the number of nests approaching 2000 in the best year. Although the island of Boavista supports the largest nesting number of loggerhead turtles in Cabo Verde (López-Jurado et al. 2000; Cozens et al. 2009; Monzón-Argüello et al. 2010; Marco et al. 2011, 2012), Santa Luzia still is a significant site, perhaps hosting more than 1% of the nesting population in the Atlantic (by comparing the data summarized in Marco et al. 2012).

The nesting data collected on the island of Santa Luzia increase the global importance of the loggerhead population of Cabo Verde, suggesting the possibility that the range of values from 12,000 to 20,000 nests annually estimated for Cabo Verde presented by Varo-Cruz (2010) and Marco et al. (2012) may be an underestimate. Nesting data from the other islands of Cabo Verde in 2011 and 2012, provided by the General Directorate of Environment, show that Santa Luzia is just as important as other (larger) main nesting islands of Cabo Verde, such as Maio, São Nicolau, and Sal (each with more than 1000 nests identified in 2012). Contrary to those islands including Boavista, where rapidly increasing pressure from large-scale beach development and tourism may have potentially serious impacts on sea turtles (Taylor and Cozens 2010; Marco et al. 2012), Santa Luzia is uninhabited and has a protected status (nature reserve). Furthermore, unlike several other islands on Cabo Verde where poaching of nesting females remains common, here poaching females or eggs is very rare. As such, it is likely that the relative importance of Santa Luzia will keep increasing, making this a priority site for loggerhead turtle conservation in Cabo Verde and even in the wider context of the Atlantic Ocean. Preliminary surveys by Biosfera on the neighboring Branco islet (3 km<sup>2</sup>), which is part of the same marine nature reserve, concluded that there is a high nesting activity on some small beaches no more than 100 m in length. Hence, the importance of the Santa Luzia marine nature reserve may yet increase in significance.

The sex ratio of turtle hatchlings currently being produced on Santa Luzia is apparently female biased, but there appears to be a good production of males. This is confirmed both by the estimates derived from incubation duration methodology and from the limited sex determination of hatchlings from histological examination of gonads. Of course, sampling was limited, and more studies are desirable. Nevertheless, these findings are important in a context of global warming, where some beaches are already seeing (and will further see) an extensive feminization of their hatchling production (e.g., Zbinden et al. 2007). This further confirms the conservation value of Santa Luzia.

The loggerhead turtles nesting in the nature reserve of Santa Luzia currently benefit from a very good protection,

thanks to the surveillance and awareness raising provided by the nongovernmental organization Biosfera I. During these 3 yrs of study, we noticed a change in attitude of fishing communities that use the reserve. The long relationship of mutual aid between Biosfera I and fishermen established a strong environmental awareness that resulted in the protection of sea turtles and other species present in the reserve from the harmful effects of sporadic visitors and other fishermen. Virtually no incidents of poaching are known to have taken place in the past few years. However, pelagic longlines may represent the single most serious global threat to loggerhead turtles (e.g., Peckham et al. 2007; Melo and Melo 2013), and the situation in Cabo Verde is particularly dire because the common practice is to kill the turtles that are still alive when they come aboard (Melo and Melo 2013). Thus, more efforts need to be deployed to tackle the conservation of this population while at sea.

In conclusion, the island of Santa Luzia represents an important nesting area for loggerhead turtles. Conservation activities are being successfully implemented and mean that this nature reserve has considerable potential as a key conservation unit of this megamarine vertebrate in the Cabo Verde archipelago and indeed in the whole Atlantic.

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