Habitat Selection and Climate Change Impacts on Green Turtles from Poilão Island, Guinea-Bissau

Final report of research conducted during the nesting season of 2013

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Background

Life-history traits of sea turtles, such as their dependence on sandy beaches, to which they exhibit philopatry for reproduction, and temperature dependent sex determination (high incubation temperatures yielding more females and low temperatures more males) make them vulnerable to climate change (Poloczanska et al 2009). Although sea turtles have endured past climate variations, it is uncertain whether they will adapt to the current rapid changes, especially since they face other human induced threats.

Several studies have suggested highly female skewed hatchling sex ratios which would worsen under climate warming (Hawkes et al 2007, Fuentes et al 2009, Fuentes et al 2010, Broderick et al 2000). Higher sand temperatures are also expected to boost hatchling abnormalities and mortality (Fuentes et al 2009), and shorten incubation periods, leading to smaller hatchlings with potentially reduced survival. Behavioral polymorphism on nest site choice with respect to microhabitat characteristics have been observed on sea turtle populations (Hawkes et al 2007, Kamel et al 2006) with implications for sex ratios and offspring survival. Whether breeders are adjusting their nesting sites according to changing environmental cues has to be investigated.

The impacts of sea level rise (SLR) have also been investigated (Baker et al 2006, Fish et al 2005, Fish et al 2008). Global mean sea levels are expected to rise 0.09 m to 0.88 m between 1990 and 2100 (IPCC, 2013), likely to cause shoreline erosion, saline intrusion into the water table and inundation of beaches and coastal areas. Significant loss of terrestrial habitat has already been predicted for several islands used by sea turtles for nesting (Baker et al 2006, Fish et al 2005, Fish et al 2008). Low-lying coastal systems, such as the Bijagós Archipelago, are particularly vulnerable to the SLR (IPCC, 2013). Sound climate projections will allow managers to prioritize conservation efforts and use realistic measures to mitigate SLR threats to sea turtle populations.

Information is yet incomplete to understand the direction of climate change impacts to marine turtles, how they may respond behaviorally, their capacity to adapt and which conservation actions might be useful in the future (Poloczanska et al 2009, Hawkes et al 2009). This is especially true for West African green turtles, as essential baseline data to evaluate how these populations are coping with current climate conditions is absent.

Poilão Island, included in the National Marine Park of João Vieira and Poilão, is the largest known green turtle rookery in Africa (Catry el al. 2002, Catry et al 2009). The diversity of available nesting habitat at Poilão seems to be of key importance potentially influencing the amount of hatchlings being produced in Poilão and their sex ratio.

The general goal of this project was to characterize the nesting habitat of green turtles in Poilão, and the consequences of nest-site selection to hatchlings survival and sex ratio, currently and in the future, according to predictions of global warming and global mean sea level rise. This project was lead through collaboration between the Institute of Biodiversity and Protected Areas of Guinea-Bissau, the research Unit of Eco-Ethology of ISPA (Portugal) and the Centre for Ecology and Conservation of the University of Exeter. Field work was conducted throughout three months, from September 1 to November 22, 2013. Field activities and results are described here.

Objectives

1. Understand the green turtle nesting distribution through the diverse available habitats at Poilão Island;

2. Investigate if there is individual preference for a specific habitat type, i.e. vegetation type, shaded vs. Open beach zone, elevation, distance to vegetation, and location along the beach ;

3. Estimate the consequences of the observed nest distribution on hatching success and hatchlings' sex ratio;

4. Model the impacts of predicted global warming on egg incubation and hatchlings' sex ratio;

5. Model the impacts of sea level rise on the nesting habitat available in Poilão;

Study Area

The Bijagós archipelago locates offshore the West coast of Guinea-Bissau and comprises 80 islands, covering a total area of ca. 10,000 km^2. Only 20 of these islands are permanently inhabited, summing to a population of 25,000 inhabitants, being its majority from the Bijagó ethnic group.

Some of the uninhabited islands are considered sacred and only visited during religious or social ceremonies. This has contributed to enhance the protection of the archipelago's vast biodiversity, which includes charismatic species such as marine turtles, manatees and hippopotamus, plus several species of migratory sea birds. This diversity is well recognized and led to the establishment of two national parks and to the designation of UNESCO Biosphere Reserve in 1996.

At the Bijagós 5 of the extant 7 species of sea turtles can be seen: green turtle *Chelonia mydas*, hawksbill *Eretmochelys imbricata*, loggerhead *Caretta caretta*, olive ridley *Lepidochelys olivacea*, e leatherback *Dermochelys coriacea*, being the first the more abundant.

Poilão (10°52'N, 15°43'W), included in the National Marine Park of João Vieira and Poilão, is a small island, with an area of 0.43 km^2, and yet it hosts the third largest green turtle rookery in the Atlantic, first in Africa (Catry et al 2002, Catry et al 2009). Poilão is the most remote island of the park, it is characterized by its low elevation, is covered by undisturbed dense tropical forest and surrounded by subtidal rocks. The climate is tropical, with a well-marked rainy season between May and October, coinciding with the nesting season.

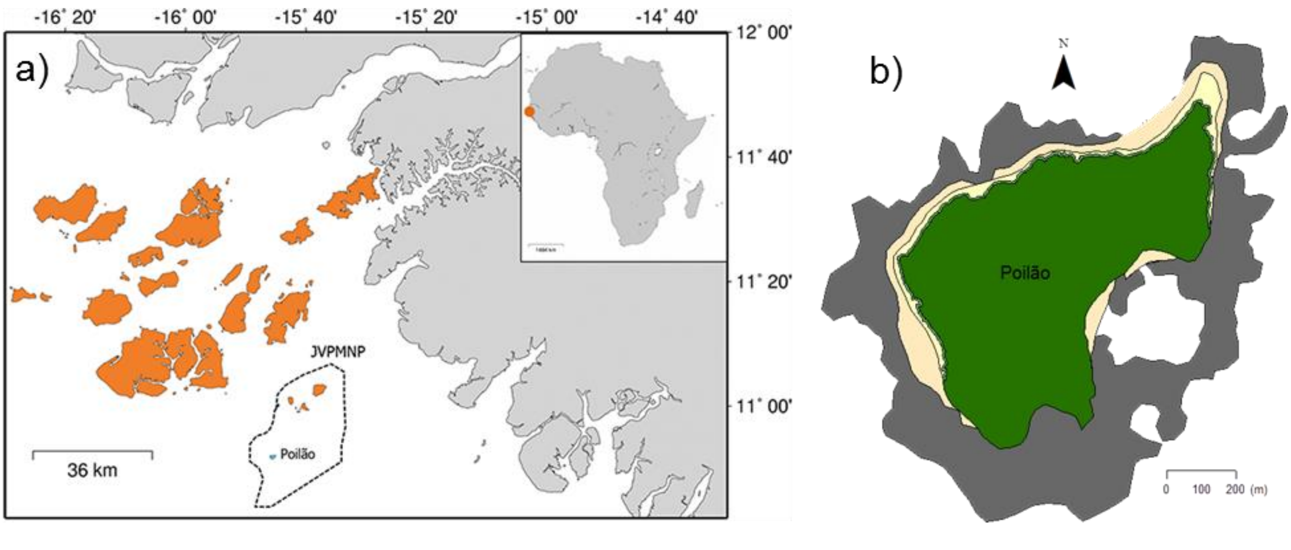

Figure 1. **a)** Location of the Bijagós Archipelago. The dashed line represents the boundaries of the National Marine Park of João Vieira and Poilão; **b)** Map of Poilão Island depicting subtidal rocks (dark grey), open beach area (pale yellow) and forest area (green).

Field Work Activities

1. **Nesting distribution according to habitat:**
   Nesters were observed at the moment of laying eggs in 539 occasions. The following characteristics of nesting site were recorded:
   - Latitude/longitude, using a hand held Garmin GPS
   - Vegetation type (tree, bush, low lying vegetation and open beach)
   - Shade vs. sun zone (or partial shade)
   - Distance along the beach
   - Distance to the vegetation

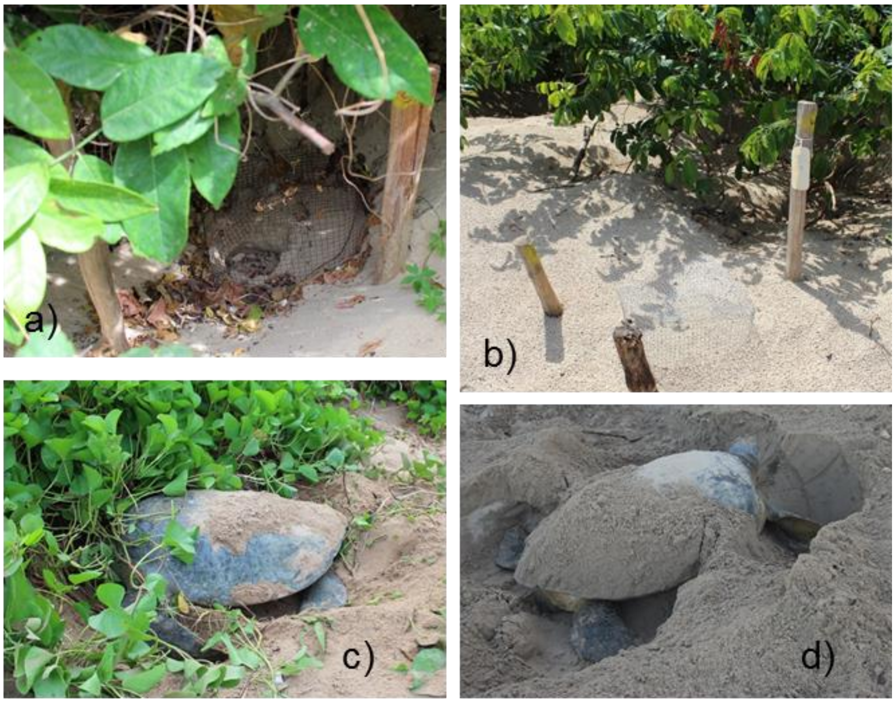

Figure 2. Example of different nesting habitats observed: **a)** total shade, under bush; **b)** partial shade, bush; **c)** low lying vegetation; **d)** open beach

2. **Individual consistency in nest-site selection:**
   A total of 200 nesters were tagged on both front flippers during the nesting season of 2013. Of these, we re-sighted 69 nesting, in a total of 75 encounters. Same characteristics of nesting site as above were recorded at each encounter.

3. **Consequences of nests' distribution on hatchlings' survival and sex-ratio:**
A total of 54 temperature data loggers were deployed inside egg chambers, while females were laying, and were left there during all the incubation period, recording temperature every hour. Nests with temperature data loggers were monitored until hatchling emergence and exhumed to evaluate nest contents and calculate hatching and emergency success. Nest depth was measured after all contents removed.

Figure 3. a) Temperature data logger; **b)** hatched green turtle eggs; **c)** measuring nest depth

4. **Modelling the impacts of global warming on hatchlings' sex-ratio:**
During the months of September, October and November, 14 temperature data loggers distributed along the nesting area of Poilão, at all suitable nesting habitats, buried at 50 cm depth, recorded sand temperature each hour. Two additional temperature data loggers recorded sand temperature at 50 cm depth and air temperature throughout the whole year. Data from incubation temperatures, sand and air temperatures and the sex ratio estimated for the 2013 nesting season will be used to model impacts of predicted increased temperatures (IPCC, 2013).

5. **Modelling impacts of global mean sea level rise on the nesting habitat at Poilão:**
Beach profile, from the low water mark up to the vegetation line was measured, using the Abney level method, every 100 metres, throughout the nesting area of Poilão. The beach profiles will be used to generate a digital elevation model of the island and together with the nests' distribution will be used to model the impact of expected sea level rise on this population of green turtles.

Results

1. **Nesting distribution according to habitat:**

During the nesting season of 2013, the locations of 539 nests distributed along the beach of Poilão were marked with GPS (figure 4 a)). Most nests were on open beach (51%), and 40% of nests had some type of vegetation: tree (12%), bush (25%) and low lying vegetation (12%).

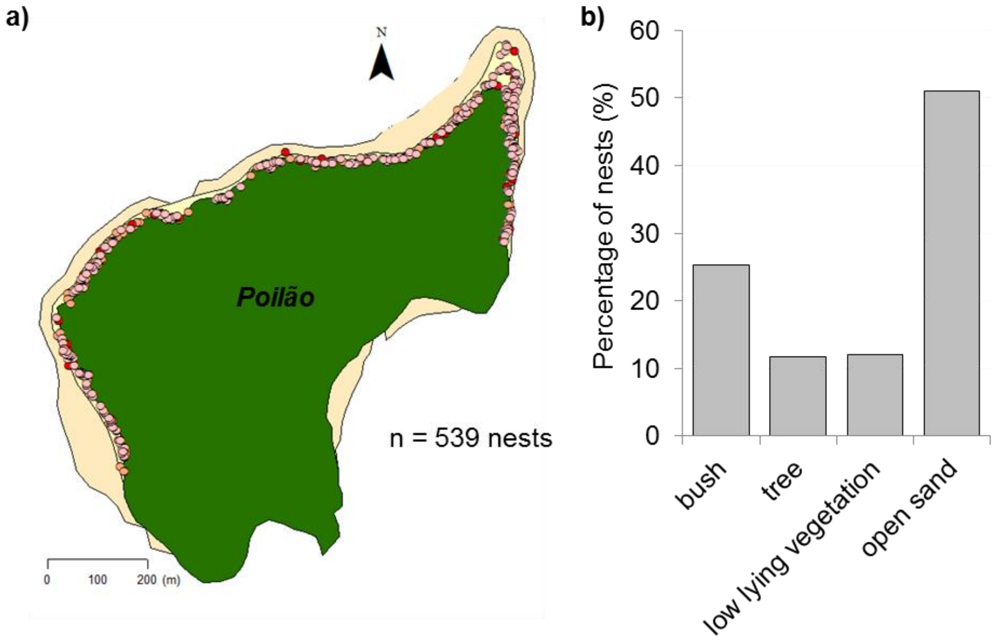

Figure 4. a) Map of Poilão Island showing the location of nests characterized according to habitat and location (n=539); **b)** distribution of nests in Poilão, in percentage, according to vegetation type.

2. **Individual consistency in nest-site selection:**

Of the 200 tagged nesters 69 were seen nesting again; 76 % were seen nesting twice, 21 % were seen nesting three times and 3 % were seen nesting four times (figure 5 a)). Looking at individual consistency on nest-site choice we observed that both for i) location along the beach, ii) vegetation type, and iii) shade vs. sun zones, two thirds of the turtles returned to the same nest-site conditions in consecutive lays vs. only one third that changed nest-site conditions in consecutive lays (figure 5 b)).

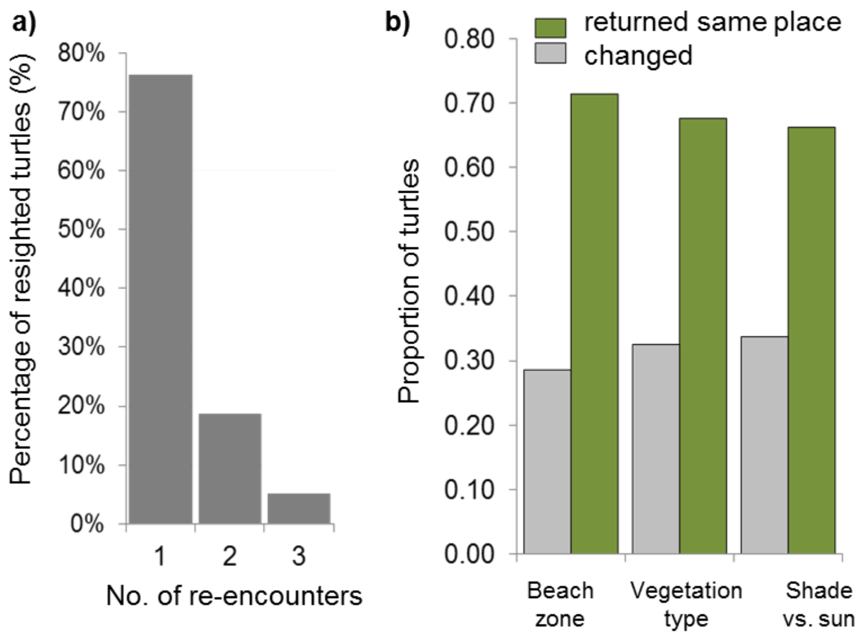

Figura 5. a) distribution, in percentage, of turtles re-encountered once, twice and three times, since first tagged; **b)** Proportion of turtles that returned to the i) same area along the nesting beach, ii) same vegetation type, and iii) same shade vs. sun zone and turtles that changed.

3. **Consequences of nest distribution on hatchlings' survival and sex-ratio:**

To access the consequences of nesting site on hatching success and hatchlings' sex ratio we used the 54 nests for which more detailed information and temperature data loggers were available (figure 6). These nests were monitored daily to assure that other turtles would not destroy them during their nesting activities.

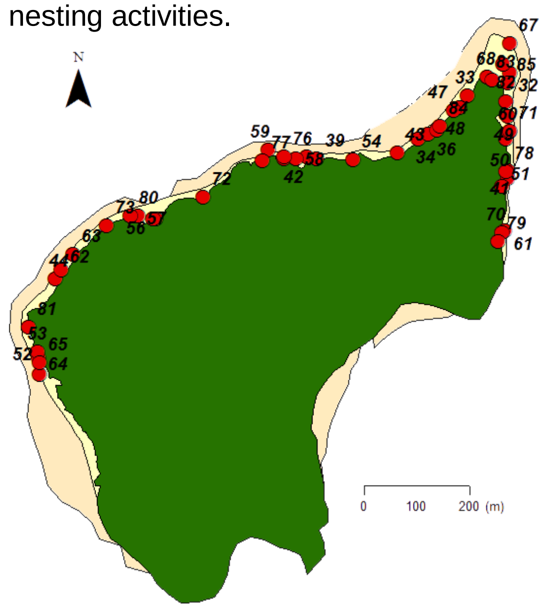

Figure 6. Distribution of nests with temperature data loggers inside egg chamber.

- **Hatching success**

Of the 54 monitored nests four did not hatched and three had hatching success ≤ 6%, considered also as non-hatched nests, therefore there was a mortality of 13 % of the monitored nests. Vegetation type, shade vs. sun zone, location along the beach and incubation temperatures did not significantly affect hatching success. There was – however - a significant positive effect of nest elevation on hatching success, and a significant negative effect of nest depth (figure 7).

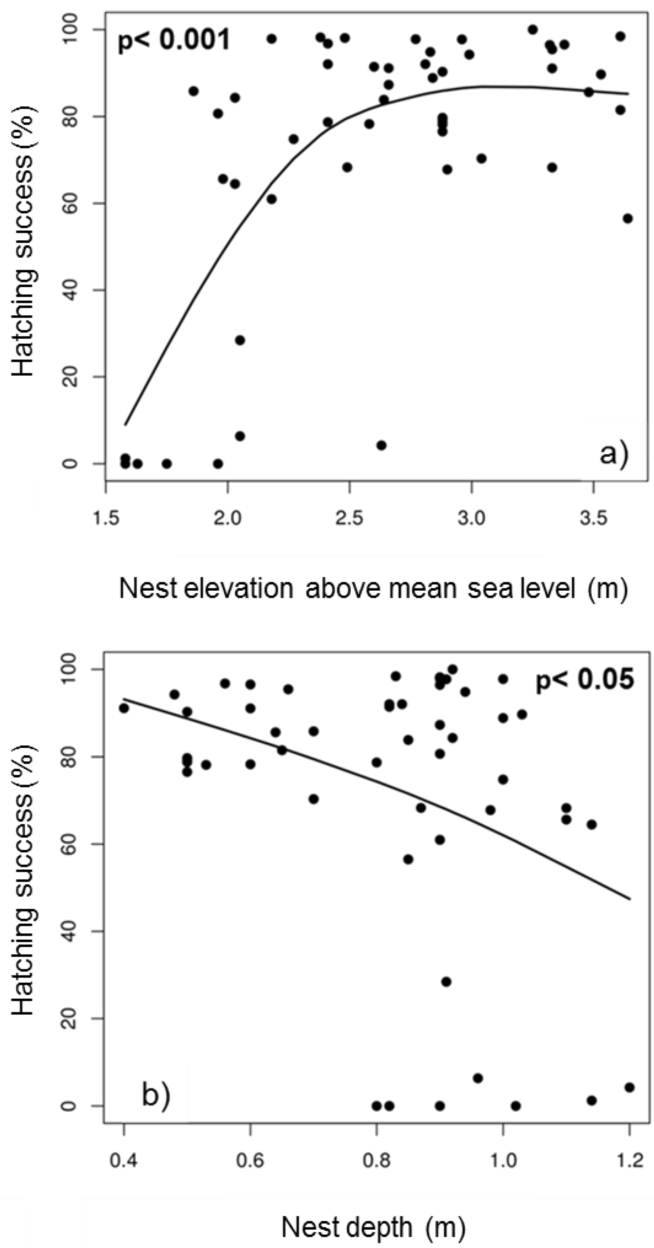

Figure 7. a) Effect of nest elevation on hatching success. **b)** Effect of nest depth on hatching success. In both graphs the black line represents the best fit to the observed values (black dots).

- **Sex-ratio**

We gathered incubation temperatures of 45 nests which successfully hatched (from the initial 54 seven did not hatched, and the temperature data loggers were lost from two other). Mean temperatures during the middle third of incubation (period during which the sex is determined) ranged from 27.5°C to 32.17°C. These values are well within the range of temperatures producing both sexes. Incubation periods ranged from 48 to 68 days, including the lag period from hatching to emergence of hatchlings. Considering the observed incubation temperatures and a pivotal temperature of 29.4°C (temperature at which both males and females are produced in equal proportion, Godfrey and Mrosovsky 2006), it is expected that 60% of the nests will have female-biased sex-ratio and that 40% will have male-biased sex-ratio, leading to an overall balanced sex-ratio (figure 8).

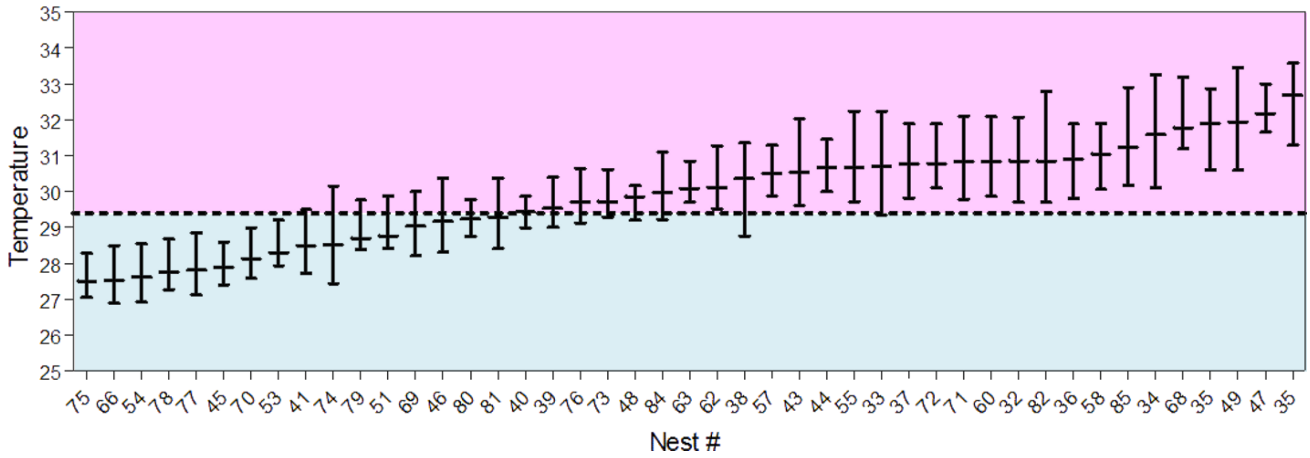

Figure 8. Minimum, mean and maximum incubation temperatures, during the middle third of incubation, of 45 nests, distributed across different habitats at Poilão. Temperatures leading to female-biased sex-ratios are in pink, and temperatures leading to male-biased sex-ratios are in blue.

4. **Modelling impacts of global warming on hatchlings' survival and sex ratio** and 5. **Modelling impacts of global mean sea level rise on the nesting habitat at Poilão:**

As we went through the data gathered thus far, it became evident the need for more information, to improve models of climate change impacts. Particularly, to model the effects of increased sand temperatures on hatchlings' sex ratio it is important to add more data on incubation temperatures from the month of August, during the 2014 nesting season. August and September are the months of peak nesting activities; however, due to restrictions to access the island of Poilão in August 2013, we could only start field work by September 2013. Likewise, to improve the model of impacts of global mean sea level rise on the nesting habitat we aim to repeat measurements of beach profiles and also use a different methodology to create a 3D digital elevation model, based on imagery, to increase accuracy and detail. Furthermore we aim to survey nearby islands for suitable nesting habitat.

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