Assessing the potential effects of varying levels of marine plastic pollution in the nesting habitat of loggerhead turtles (*Caretta caretta*) in Boa Vista Island, Cabo Verde

Kate Yeoman[1,2], Airton Jesus[1], Robert Briers[2], Thomas Reischig[3]

1: Fundação Tartaruga, Cabo Verde; 2: Edinburgh Napier University, United Kingdom; 3: Turtle Foundation, Germany

Figure 1 shows an image of a recently hatched loggerhead turtle becoming entangled in fishing nets on its journey from the nest to the sea on Boa Esperança beach. A common occurrence on the northern nesting beaches in Boa Vista.

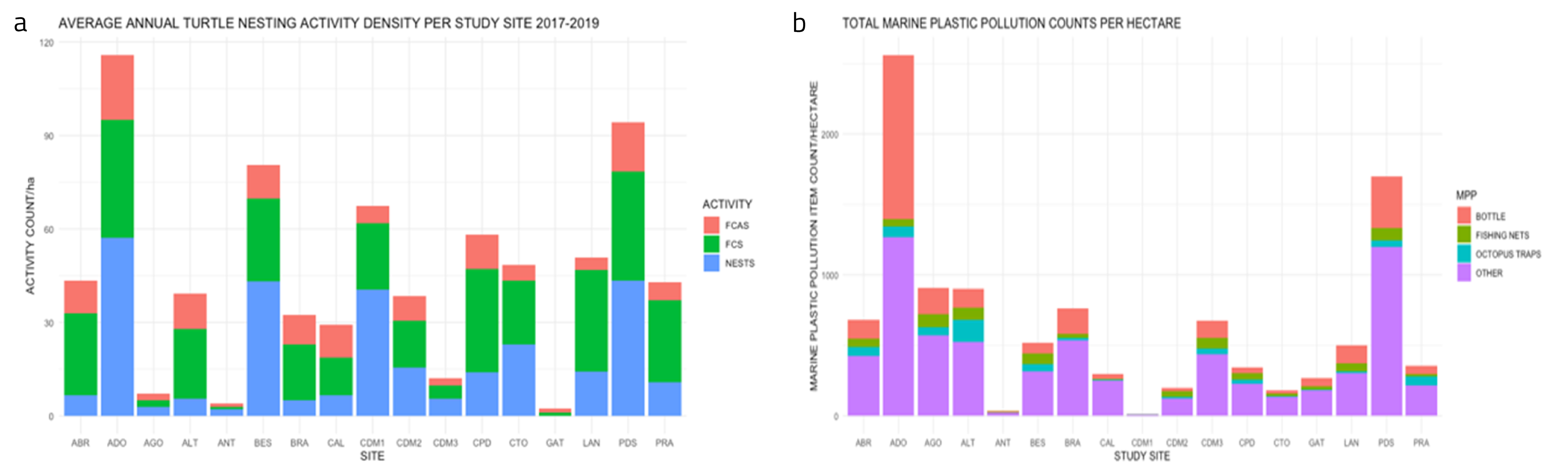

Figure 3 shows (a) the distribution of turtle nesting activity and (b) the distribution of types of MPP across the 17 beaches.

BACKGROUND

Cabo Verde is the third largest rookery for **loggerhead turtles** (*Caretta caretta*) in the world and is categorised by IUCN as **'endangered'**. The study of impacts of plastic on turtle nesting activity and their habitats is virtually non-existent. The northern and eastern coast of Boa Vista Island is a recognised hotspot for nesting loggerhead turtles; however, it is also subjected to vast quantities of marine waste carried via the Canary Current. Whilst many studies have looked at the ingestion of plastics in sea turtles[1,2,3] and quantifying plastic in the oceans[4], there is a stark lack of information relating to the impact of **Marine Plastic Pollution** (MPP) on beach habitats. This is perhaps due to the difficulties associated with trying to quantify and characterise a variable which seems infinite. As a **Small Island Developing State** (SIDS), Cabo Verde is significantly at risk from MPP and the impacts associated and is also classified as an important area where conservation action is a priority[5].

There are many ways in which we do not fully understand how sea turtles are impacted by plastics. Sandy beaches and dune systems which serve as important nesting habitats are subjected to **microplastic** deposition, which can lead to: changes in temperature of the sand leading to skewed sex ratios or in more extreme cases, death of the eggs; production and leakage of toxic chemicals into the eggs; increase in porosity of the beaches, changing composition, granulometry, humidity, and moisture content of the nesting habitat; physical obstacles blocking the pathway for hatchlings to reach the sea[6,7,8].

SCOPE OF THIS WORK

This two-part study aims to identify and evaluate potential impacts on the behavioural ecology of nesting turtles and the nesting success and subsequent viability of clutches laid along the northern coast of Boa Vista.

1) Drones were deployed to take high resolution images which were later analysed using QGIS and individual pieces of plastic were identified, assigned a GPS location and categorised. Daily patrols were conducted during the nesting season and GPS location data and type of nesting activity were recorded. Both plastic and turtle activity abundances and distributions were compared across 19.5 km of coastal habitat.

2) The second part of this study included a qualitative in-situ study conducted from July-October 2022, evaluating hatching success of nests and samples of sand taken at incremental depths directly above the nest. Preliminary results found turtle nesting behaviour was indeed affected by the density of plastic items present and the viability of clutches decreased as the amount of plastic found in the vicinity of the nest increased.

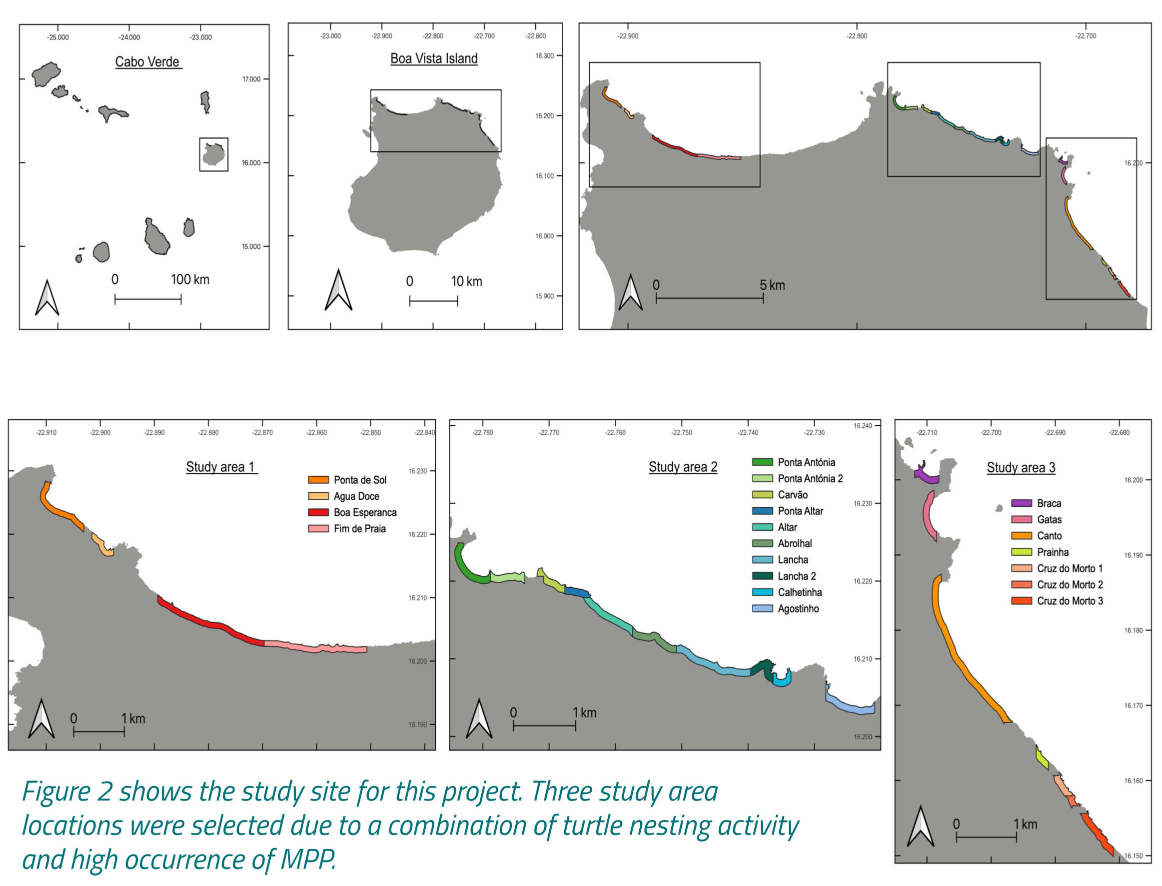

Figure 2 shows the study site for this project. Three study area locations were selected due to a combination of turtle nesting activity and high occurrence of MPP.

RESULTS

- A total of **116,901 items of marine plastic pollution** >20 cm in length were identified, an average of **6,082 items per km of coastline**.
- **Non-nest activity density: FCs + FCAs is significantly related to the density of total MPPs found in the same hectare**.
- The rate of non-nesting activity increased at a rate of 1% per unit of MPP (0.0028 ± 0.0012, $z = 2.36$, $P = 0.018$). When each type of MPP was run as a single predictor for non-nest activity, significant predictors were: octopus traps and other.

When all different types of MPP were entered into this model together, **the total density of FCs and FCAs combined was significantly related to the density of MPP**. Significant variables were: Total rubbish (0.011 ± 0.005 items of MPP/ha, $z = 2.19$, $P = 0.029$), bottles, fishing nets and 'other'.

Levels of plastic are significantly negatively correlated with hatching success of unpredated nests, both in-situ and in the hatchery: mass ($r = -0.85$), number of items ($r = -0.5$) and length of plastics ($r = -0.71$). See figure 4. Additional high r scores were found between HSR and total plastic mass found at 40–50 cm and 30–40 cm and the HSR and the total number of items at 0–2 cm.

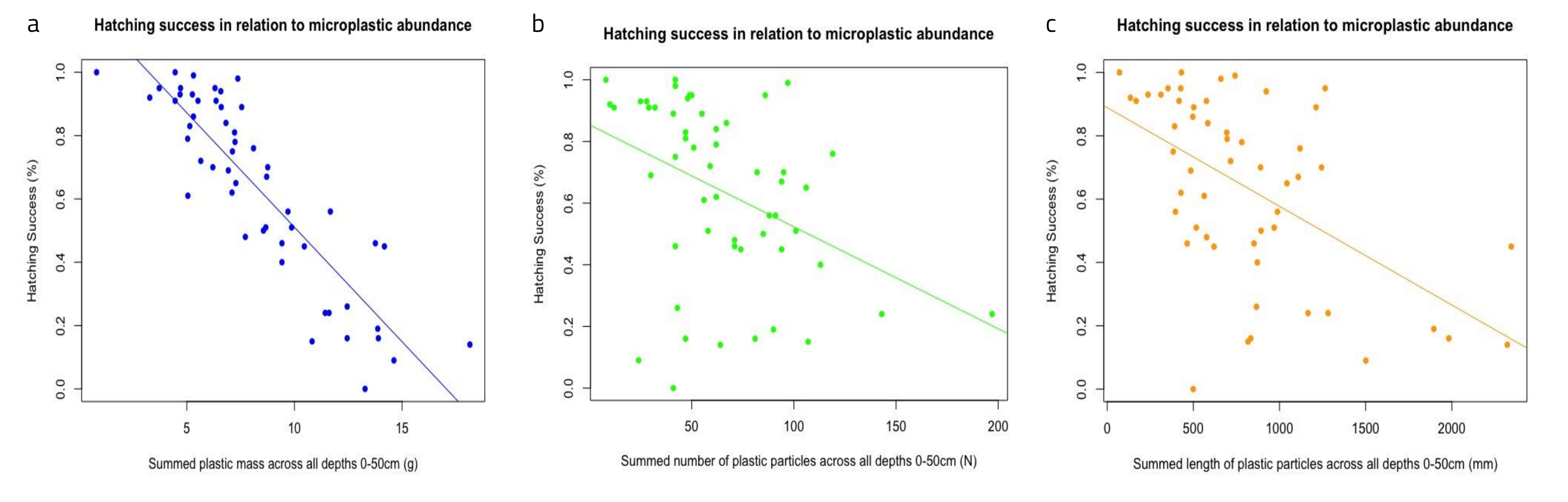

Figure 4 shows the relationship between hatching success rates and summed microplastic abundance from 0–50 cm depth in terms of (a) mass, (b) number and (c) length.

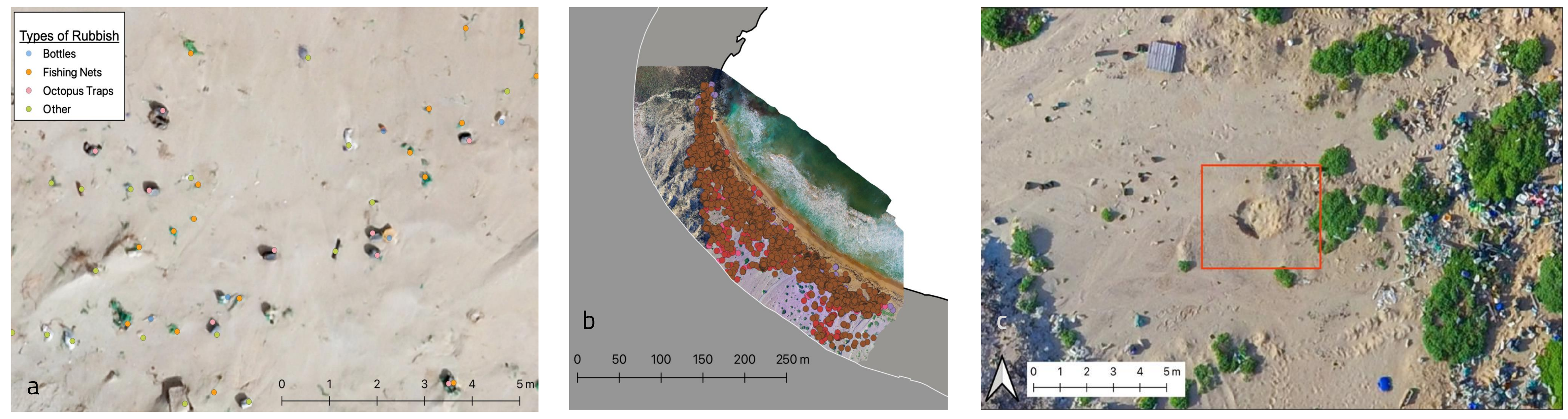

Figure 5 (a) shows how each image map was magnified to a 1:50 scale to allow for identification and marking of each plastic item according to the four categories shown; 4(b) shows the beach Ponta do Sol with the total MPP points in brown and the total nesting activity points in red in a layer below; 4(c) shows a drone image of a turtle nest in Ponta do Sol , the nest is in an area where there is no obvious large items of MPP but the turtle clearly had to pass through a lots of MPP to arrive at this location.

DISCUSSION

- This study showed that nesting turtles can be affected by plastics in the nesting habitats in a variety of ways.
- There was a **significant relationship** between the density of non-nesting activities recorded and the density of MPP.
- Areas with more MPP are less suitable for turtles to complete their nesting attempts.
- Total mass and total number of plastic fragments found in all depths are **significantly negatively correlated** with hatching success.
- The exact relationship between plastics and hatching success cannot be inferred from this analysis.
- This study does imply that removing the smaller MPP particles from the surface sand and up to 50 cm deep should be made a **priority** when planning turtle conservation strategies.
- Research which investigates other potential impacts of nesting behaviour, such as the length of time spent trying to find a suitable nesting site, the length of the track to and from the ocean in relation to the quantity of MPP would be of interest.
- Plastic aggregation is common with offshore islands which have tendency to become waste accumulators[9] leaving these islands with not only environmental issues but social ones too. SIDS such as Cabo Verde must manage not only the waste generated by their own territory, but those produced externally too.
- There **is no single solution** to the Marine Plastic Pollution crisis, a synergy between various international sectors and stake-holders is now needed to address this challenge.

METHODS

Marine Plastic Pollution vs Nesting Success Rate (NSR)

- ***Nesting behaviour:*** Between the months of June to October 2017–2019, nesting behaviour and location was recorded in the study site in figure 1. Behaviours were characterised into: False Crawls (FC; False Crawl with Attempt (FCA) and Nest (N).
- ***Beach mapping:*** Beaches were recorded with aerial surveys with drones to obtain images of the beach states. To obtain image sequences for mapping the software DroneDeploy (DroneDeploy, 1045 Bryant St #300, San Francisco, CA, USA) was used to control flight height, flight path and image acquisition. Georeferenced image maps were created with the DroneDeploy software service while correcting for image distortion. See figure 5b.
- ***Trash quantification:*** To count plastic items, the maps were magnified to a 1:50 scale, in which a patch of the area of 15 x 10 m was displayed. Every item (>20cm) was recorded by a mouse click, with each click creating a georeferenced point object on a shapefile layer in QGIS. The plastic items were classified into four main categories: bottles, fishing nets, octopus traps and other. See figure 5a.
- ***Evaluation:*** All statistical analysis were conducted using R studio, (RStudio Team, 2020) with a significance threshold of $p>0.05$ for all tests. A Spearman's Correlation matrix was run, then a negative binomial Generalised Linear Model (GLM) glm.nb function in the package "MASS" and ANOVA analysis with Chi-squared test was ran to test the hypothesis that turtle nesting behaviours is related to the density of MPP. The dependent variable (activity density) and independent variables (MPP density) + topography (as.factor) + site were included in the model.

Microplastic vs Hatching Success Rate (HSR)

- ***MPP sampling:*** During the 2022 turtle nesting season, MPP samples were collected from 19 marked in-situ nests in Boa Esperança, Agua Doce and Ponta de Sol and from 32 hatchery nests located within Boa Esperança during excavations. This study adapted a sampling method used by *Duncan et al. (2018).* Surface samples 2 cm in depth were taken 1 m x 1 m with the location of the nest at the centre of the quadrat to produce a $0.02 m^3$ sample. This is a standardised and frequently used sampling method for surface sand which allows for direct comparison worldwide. Then, $0.004 m^3$ samples (20 cm x 20 cm x 10 cm) directly above the nest were taken at incremental depths from 2-10 cm, 10.1-20 cm, 20.1-30cm, then the upper surface of the nest and after excavation, the lower surface of the nest (~50 cm).
- ***Evaluation:*** The samples were multiplied to produce densities per m^{-3}. These densities were then run in a correlation matrix using Spearman's hatching success and the total mass, number and the length of the plastic items found at each depth and in each nest. They were tested for normality and then run through a GLM.

REFERENCES

1. Bjorndal, K. A., Bolten, A. B., & Lagueux, C. J. (1994). Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. *Marine pollution bulletin*, *28*(3), 154-158.

2. Bugoni, L., Krause, L., & Petry, M. V. (2001). Marine debris and human impacts on sea turtles in southern Brazil. *Marine pollution bulletin*, *42*(12), 1330-1334.

3. Gall, S. C., & Thompson, R. C. (2015). The impact of debris on marine life. *Marine pollution bulletin*, *92*(1-2), 170-179.

4. Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science*, *347*(6223), 768-771.

5. Kueffer, C., & Kinney, K. (2017). What is the importance of islands to environmental conservation? *Environmental Conservation,* 44(4), 311-322.

6. Carson, H. S., Nerheim, M. S., Carroll, K. A., & Eriksen, M. (2013). The plastic-associated microorganisms of the North Pacific Gyre. *Marine pollution bulletin*, *75*(1-2), 126-132.

7. Duncan, E. M., Arrowsmith, J., Bain, C., Broderick, A. C., Lee, J., Metcalfe, K., ... & Godley, B. J. (2018). The true depth of the Mediterranean plastic problem: Extreme microplastic pollution on marine turtle nesting beaches in Cyprus. *Marine pollution bulletin*, *136*, 334-340.

8. Nelms, S. E., Duncan, E. M., Broderick, A. C., Galloway, T. S., Godfrey, M. H., Hamann, M., ... & Godley, B. J. (2016). Plastic and marine turtles: a review and call for research. *ICES Journal of Marine Science*, *73*(2), 165-181.

9. CBD (2014) Island Biodiversity – Island Bright Spots in Conservation & Sustainability. Montreal, Canada: Convention on Biological Diversity.

ACKNOWLEDGEMENTS

This project was conducted with the support of Fundação Tartaruga and Turtle Foundation. Thank you to all the rangers, coordinators and volunteers who collected the data and relentlessly continue to contribute to the protection of the species. Thank you to the drone team who collected the images used for analysis.

Thank you to Projeto Tartaruga for sharing temperature data and to Diana Guedes and Leila Almeida for your encouragement and for sharing your knowledge.