Global Distribution Models for Whale Sharks

(Assessing Occurrence Trends of Highly Migratory Marine Species)

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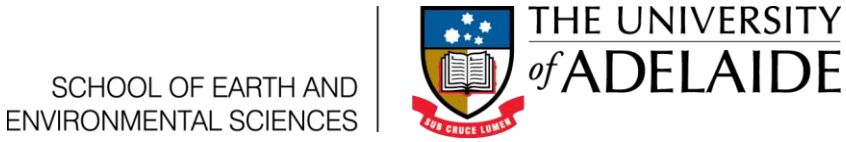
(M.Sc. Modelling the Marine Environment)

A thesis submitted to the



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(Quando eu era pequenina...)

- A minha mãe ensinou-me como explicar sempre o que eu queria.
- O meu pai ensinou-me que não podemos ter sempre o que queremos no momento em que queremos.

Completar o meu doutoramento teria sido impossível se eu não tivesse aprendido estas duas lições.

Esta tese é dedicada aos meus pais.

Translation:

(When I was a little girl...)

- *My mum taught me how to always explain what I wanted.*
- *My father taught me that we cannot always have what we want, when we want it.*

Completing my Ph.D. would never have been possible without these two lessons

I dedicate my Ph.D. to my parents.

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SUMMARY

The processes driving distribution and abundance patterns of highly migratory marine species, such as filter-feeding sharks, remain largely unexplained. The whale shark (Rhincodon typus Smith 1828) is a filter-feeding chondrichthyan that can reach > 18 m in total length, making it the largest extant fish species. Its geographic range has been defined within all tropical and warm temperate waters around the globe. However, even though mitochondrial and microsatellite DNA studies have revealed low genetic differentiation among the three major ocean basins, most studies of the species are focussed on the scale of single aggregations. Our understanding of the species' ecology is therefore based on only a small proportion of its life stages, such that we cannot yet adequately explain its biology and movement patterns (Chapter I). I present a worldwide conceptual model of possible whale shark migration routes, while suggesting a novel perspective for quantifying the species' behaviour and ecology. This model can be used to trim the hypotheses related to whale shark movements and aggregation timings, thereby isolating possible mating and breeding areas that are currently unknown (Chapter II). In the next chapter, I quantify the seasonal suitable habitat availability in the Indian Ocean (ocean basin-scale study) by applying generalised linear, spatial mixed-effects and maximum entropy models to produce maps of whale shark habitat suitability (Chapter III). I then assess the inter-annual variation in known whale shark occurrences to unearth temporal trends in a large area of the Indian Ocean. The results from the Indian Ocean suggest both temporal and spatial variability in the whale sharks occurrence (Chapter IV). Therefore, I applied the same analysis to the Atlantic and Pacific Oceans using similar broad-scale datasets. While the results for the Pacific Ocean were inconclusive with respect to temporal

trends, in the Atlantic Ocean I found preliminary evidence for a cyclic regularity in whale shark occurrence (Chapter V). In Chapter VI, I build a model to predict global whale shark habitat suitability for the present, as well as within a climate change scenario for 2070. Finally, Chapter VII provides a general discussion of the work developed within this thesis and presents ideas for future research.

STATEMENT OF ORIGINALITY

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Ana Micaela Martins Sequeira

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