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JAMES COOK UNIVERSITY
AUSTRALIA

Multidisciplinary Insights into the Conservation and Biology of Sea Turtles in Mozambique

Thesis submitted by

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Bsc (Hons) Marine science & conservation and wildlife biology, Murdoch University

For the degree of Doctor of Philosophy
in the College of Marine and Environmental Sciences,
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Townsville, Australia
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1- Introduction	n/a	
2- Citizen science	Williams JL, Pierce SJ, Fuentes MMPB, Hamann M (2015). Effectiveness of recreational divers for monitoring sea turtle populations. *Endangered Species Research* 26:209–219. Doi:10.3354/esr00647	I designed the study. Pierce and I conducted the fieldwork. I analysed the data with advice from Hamann and Pierce. I wrote the manuscript with editorial support from all authors.
3- In-water ecology	Williams JL, Pierce SJ, Rohner CA, Fuentes MMPB, Hamann M (2017). Spatial distribution and residency of green and loggerhead sea turtles using coastal reef habitats in southern Mozambique.	I designed the study and conducted the fieldwork. I analysed the data with advise from Rohner, Pierce, Hamann. I wrote the manuscript with editorial support from all authors.

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4-	Illegal take & use	Williams JL, Pierce SJ, Fuentes MMPB, Hamann M (in prep) Understanding the illegal take of marine turtles in Mozambique. Target journal: *TBA*	I designed the study with Pierce. I conducted the transects with local volunteers. I completed the data analysis and wrote the manuscript with support from all authors.
5-	Motives and drivers for take	Williams JL, Pierce S.J, Fuentes MMPB, Meletis Z, Hamann M (in prep) Drivers and motives for illegal use of sea turtles. Target journal: *TBA*	I designed the study with assistance from Pierce, Hamann and Fuentes. Interviews were conducted with assistance from local translators. I analysed the interview data and compiled the results. All authors assisted with editorial support.
6-	Perception of threats	Williams JL, Pierce SJ, Hamann M, Fuentes MMPB (in review) Using expert opinion to fill the gaps on sea turtle threats: A case study in a data-poor context. Aquatic	I designed the study with Fuentes and Hamann. I collected the interviews and analysed the data and Hamann validated interview coding. I wrote the chapter and Fuentes, Hamann and Pierce

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7- Discussion	n/a	

Ethics Statement

All necessary permits to conduct this study were obtained from JCU animal ethics and human ethics committees (permit number A1862 and H4714 respectively).

Copyright Declaration

Every reasonable effort has been made to gain permission and acknowledge the owners of copyright material. I would be pleased to hear from any copyright owner who has been omitted or incorrectly acknowledged.

Outputs During Candidature

➢ Papers Published or Intended for Publication

Williams JL, Pierce SJ, Fuentes MMPB, Hamann M. (2015) Effectiveness of recreational divers for monitoring sea turtle populations. *Endangered Species Research* 26:209–219. Doi:10.3354/esr00647 (Chapter 2).

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➢ Selected technical reports

Fernandes RS**, Williams JL**, Trindade J. (2016) Monitoring, tagging and conservation of marine turtles in Mozambique: Annual report 2015/16. 28 pp. Maputo, CTV.

Fernandes, RS., **Williams JL.**, Trindade J. Pereira MAM. (2015) Monitoring, tagging and conservation of marine turtles in Mozambique: Annual report 2014/15. 21 pp. Maputo, CTV.

Fernandes R, **Williams JL**, Louro C, Pereira MAM. (2014) Monitoring, tagging and conservation of marine turtles in Mozambique: Annual report 2013/14. Maputo. CTV

Pereira MAM, Litulo C, Santos R, Leal M, Fernandes RS, Tibiriçá Y, **Williams JL**, Atanassov B, Carreira F, Massingue A, Marques da Silva I, (2014) Mozambique marine ecosystems review. Technical report submitted to Fondation Ensemble. 139 pp. Maputo, Biodinâmica/CTV.

➢ Other Publications

Williams JL, Pierce SJ, Fuentes MMPB, Hamann M. (2016) The tradition of take: sea turtle consumption in Dovela, Mozambique. *African Sea Turtle Newsletter* 5: 27 - 31.

Fernandes RS, **Williams JL**, Trindade J, Pereira MAM. (2015) Marine turtles in Mozambique: Results from the 2014/2015 nesting season. *African Sea Turtle Newsletter* 4: 35 - 38.

Williams JL. (2013) Moving Mozambique's Sea Turtles Off the Dinner Menu: Using World Turtle Day as a Tool to Deliver Critical Education and Outreach Programs. *African Diver* 27: 34 - 42.

Williams JL. (2013) Searching for practical solutions to sea turtle poaching in Mozambique. *African Diver 26*: 18 – 25.

Williams JL. (2012) How sea turtles get sexy. *Submerge*, SCUBA Diving magazine, South Africa. June-July 2012: 18.

Gekoski A, **Williams JL**. (2012) Turtles in Turmoil. *Divesite Magazine*, South Africa. July 2012: 24-33.

- Conference Presentations

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Williams JL, Pierce SJ, Fuentes MMPB, Hamann M. (2013) Using citizen science to monitor sea turtles. Poster Presentation. Western Indian Ocean Marine Science Association Biennial Symposium 8. 28th Oct – 2nd Nov 2013, Maputo, Mozambique.

Williams JL, Pierce SJ, Fuentes MMPB, Hamann M. (2013) Citizen science for sea turtles? Enlisting recreational divers for monitoring sea turtles in Mozambique. 33rd International sea turtle symposium. Baltimore, USA.

Williams JL, Pierce SJ, Fuentes MMPB, Hamann M. (2012) Citizen science – a case study of marine turtle monitoring from Mozambique. Australian marine turtle biennial symposium (2012) 15th- 16th Sept, 2012. Buderim, Queensland.

Thesis Abstract

Five of the world's seven species of sea turtles have been documented to use Mozambican habitats. While they are thought to be extensively distributed throughout Mozambican coastal waters, and the offshore waters of the Mozambican Channel, little is known about these populations. Specifically, information about the state and structure of sea turtle populations (population size estimates, species composition, age class distribution, movements of animals into and out of the study area, residency, habitat use and preferences) was scarce or non-existent for Mozambique. Therefore, my research adopted several complementary research techniques to increase knowledge on sea turtles in their foraging grounds and their exposure to human impacts.

The major research aim of my thesis is to understand factors related to the distribution, abundance and use of sea turtle populations within the Inhambane region, Mozambique, and use this knowledge to inform and improve conservation and management efforts.

In Chapters 2 and 3, I explore the use of citizen science and photo-identification (photo-ID) as tools to facilitate the collection of data on turtles encountered in-water. I found that citizen science is a useful tool for collecting basic biological information, particularly when coupled with photo-ID encounters. While the quality of dive log records was improved by having a few well-trained and consistent contributors, the photo-ID database benefitted from broadened public involvement. Results from the generalised linear modelling of the dive log data (Chapter 3) suggested that sightings and abundance of turtles were influenced by environmental conditions. It was also evident that factors such as visibility and diving depth

lead to availability and perception bias in the citizen scientists' records. It is important to be aware of such biases since they reflect physical environmental diving conditions rather than habitat or behavioural predictors that influence sea turtles. Overall, citizen science coupled with photo-ID datasets provided the first details of Mozambique's foraging sea turtle populations. In Chapter 3, I described the use of coastal reefs by green and loggerhead sea turtles in Inhambane, Mozambique. Based on population models from the photo-ID dataset, both green and loggerhead populations were small but present year-round. Regardless of species, sea turtles favoured coastal nearshore waters and relatively shallow reef systems, which make them vulnerable to interaction with small scale fisheries (SSF). Impacts of SSF is unlikely to be consistent between species or age-classes. My findings suggest that the long-term residency of late-stage juvenile greens in these nearshore and shallow habitats make them most vulnerable to interactions with SSF.

In Chapter 4, I investigated the prevalence of illegal take of sea turtles in a coastal region of Mozambique – the Tofo area, Inhambane Province - and conducted a national-scale literature review. Transect- based sampling in the sand dunes demonstrated that the Tofo area and greater Inhambane peninsula are a hotspot for take of sea turtles. The literature review documented year-round take of sea turtles to occur through much of Mozambique. Use of sea turtles focused on their meat, and it was rare to detect more than an empty carapace or old bones. Small scale fisheries interact with turtles in their favoured habitats (close to reefs systems) in coastal waters, particularly in the south of the primary study area, between Praia do Tofinho and Praia de Rocha. Based on interviews with fishers, the opportunistic take of turtles is prevalent and widespread (Chapter 5) in Inhambane Province. A targeted marine megafauna multi-species fishery exists in the study area. Widespread use of gillnets and long-lines occurs and these fishing gears are favoured because of their non-selectivity and ability to capture turtles and other species. Sea turtle capture in these fisheries is neither bycatch nor accidental.

Interviews with fishers (Chapter 5) indicated that the motives and drivers influencing fishers to illegally take sea turtles was variable between communities and individuals. In the two fishing communities surveyed, opportunities for alternative livelihoods were lacking or insufficient to supplement or replace their reliance on fishing activities. Five of the six major drivers identified in Chapter 5 reflect Mozambique's low socio-economic status. Similarities were evident between the drivers and motives of illegal take of turtles and the terrestrial mammal bushmeat hunting and trade. The majority of fishers had multiple motives for participating in illegal take of sea turtles. Awareness of turtle protection laws amongst fishers was high, although compliance was low. This suggests that simple campaigns to increase awareness of turtle legislation will have little impact in deterring illegal take. Future conservation efforts will need to address food security, livelihoods options and aim to minimise the number of motives an individual fisher or community may have to participate in illegal take.

I solicited opinions from local experts to quantitatively rank threats and investigate the context of conservation and management efforts underway in Mozambique (Chapter 6). Consensus of expert opinions revealed the most pressing threats to sea turtles were fisheries-related (bycatch from commercial trawling, SSF bycatch and hunting of nesting turtles). The top-ranking threat, bycatch within the commercial shallow-water prawn trawl industry, could be easily mitigated with effective implementation of pre-existing Turtle Exclusion Device legislation. This is not the case for the other two threats, which given their nature are likely to involve extensive changes/improvements to living standards and Mozambique's overall socio-economic status. Compliance with sea turtle legislation was weak throughout the country and experts identified improving enforcement efforts as critical. Parallels are evident between the issues that hamper the conservation and management of terrestrial megafauna and marine megafauna. A holistic process will be required to solve large-scale issues (e.g. governance, corruption, compliance) and strengthen overall biodiversity conservation. Given the extremely limited funding allocated to conservation of sea turtles and the marine environment, and limited access to skilled people and resources, a prioritised list of management actions for sea turtle hotspot areas is necessary.

I conclude this study by discussing my key findings relating to the sea turtle populations using the Tofo area, the impacts they face and how and where conservation management efforts could be strengthened. I also suggest specific priorities for future research to enhance knowledge of sea turtle populations, socio-economic understanding of SSF and alternative livelihoods. A balance needs to be struck between the environment, economic development and social and cultural values of coastal people in order to achieve sustainable growth whilst preserving marine biodiversity and improving living standards.

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insert shows size and structural detail of a fishing camp, with a shading rack and elevated bench to keep catch sand-free whilst dissecting. Right insert is a close up of the fishing gear (two home-made spear guns, buoys, fins and rash vests for freediving and nylon rope gillnet) left inside camp.

Chapter 1

General Introduction

Sea turtles (species and conservation status)

Five of the world's seven sea turtle species occur in the South-Western Indian Ocean (SWIO). Sea turtles are migratory species that occupy large geographical ranges and inhabit most oceans (Musick and Limpus 1997; Plotkin 2003). Given their expansive ranges, longevity and ontogenetic habitat shifts, sea turtles face a variety of anthropogenic threats at each stage of their life history, which has ultimately rendered all species conservation dependent (Spotila 2004; IUCN 2016; Wallace et al., 2011).

Though all species share common life history characteristics, their natal philopatry and consequent limited reproductive interactions have resulted in minimal gene flow leading to the existence of separate breeding populations/stocks within species (Wallace et al., 2010). Global sea turtle populations have been categorised into regional management units (RMU's) based on their genetic distinctiveness or other life history characteristics (Wallace et al., 2010). The conservation status of specific RMU's often differ from the global status of the species. For example, Leatherback turtles (*Dermochelys coriacea*) are listed on the IUCN Red List as Vulnerable on a global scale, yet are Critically Endangered within the SWIO (see Fig. 1.1. status listing per species). Regional conservation assessments would benefit from improved biological data for all life stages of each sea turtle species, especially given that local variation in life histories has been documented (van Buskirk and Crowder 1994; Meylan and Ehrenfeld 2000).

The Indian Ocean has been highlighted as a data deficient region, as knowledge of the status and stocks of all sea turtle species in this ocean basin is patchy and incomplete (Wallace et al., 2011). The Indian Ocean hosts 18 RMUs and, of them, eight are considered to be data deficient (Wallace et al., 2011). Seventeen of the RMUs in the Indian ocean were categorised based on risk and threats (Wallace et al. 2011). Of these, 6 were considered high risk-high threat, 3 high risk-low threat, 4 low risk-low threat and 4 low risk-high threat (Wallace et al., 2011). The SWIO comprises the waters from the eastern coast of Africa between Kenya and South Africa, eastward to 74°E and from 1°S in the north to 30°S in the south. Within this region, the status of sea turtles in Mozambique, Tanzania, and Kenya is poorly known (Bourjea et al., 2009). Five sea turtle species have been documented in these nations, however their population sizes, trends and details of their distribution and aggregation hotspots are not known (Fig. 1.1). Sea turtle conservation has benefited in recent years by strong efforts by local and international NGOs in Kenya and Tanzania, but similar efforts in Mozambique have not successfully been sustained.

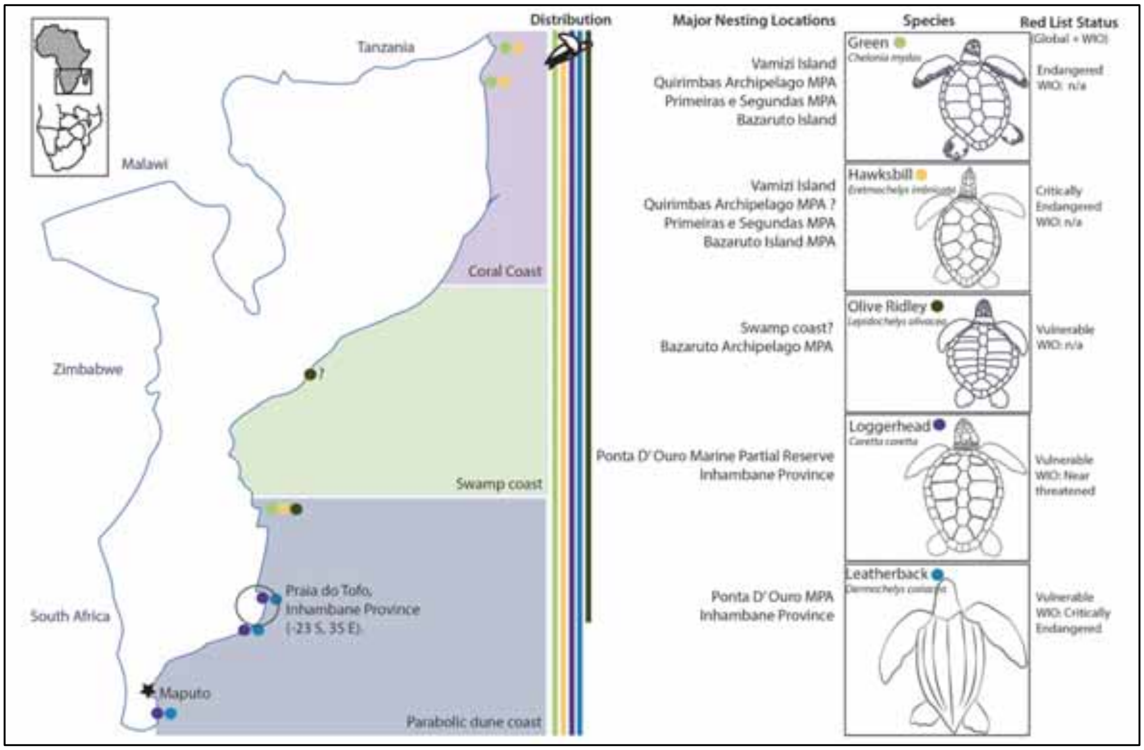


Fig. 1.1. Distribution, nesting locations and regional conservation status listings for the five species of sea turtles found in Mozambican waters. Major marine habitat types (parabolic dune coast, swamp coast, coral coast) are shown on the map Fig 1.1 (colour coded).

Green turtles (Chelonia mydas)

Green turtles are the most abundant species in the SWIO and the region hosts important nesting and feeding grounds (Hughes 1973; Frazier 1980; Mortimer 1984; Bourjea et al., 2015). Significant nesting areas include isolated islands in the SWIO (e.g. Europa, the Îles Éparses, Seychelles) and the mainland African coast from Mozambique to Kenya (Hughes 1974; Limpus et al., 2001; Rakotonirina et al., 2004; Lauret-Stepler et al., 2007; Metcalf et al., 2007; Dalleau et al., 2012; Garner et al., 2012; Bourjea et al., 2015). The highest density of green turtle nesting in Mozambique occurs in the north where approximately ~ 200 nests per year are laid (207 nests in

2015/16: Fernandes et al., 2016). The major nesting rookery in the SWIO region is at Europa Island, 600 km north-east of Inhambane, offshore in the Mozambican Channel. Seminoff (2004) reported a 32% reduction in regional SWIO green populations when compared with historic populations. However, population recovery and even growth is evident (Europa: 3% increase year^{-1} and Grande Glorieuse: 6% increase year^{-1}, Lauret-Stepler et al., 2007; Mayotte is stable, Bourjea et al., 2007). It is estimated that annually there are >10 000 nesting green females within the region (SWOT online turtle database; Kot et al., 2013; Mellet 2015).

The coastal waters of Mozambique, the greater Mozambican Channel and Madagascan coastal waters are recognized as an important feeding ground for juvenile green turtles (Bourjea et al., 2007). Green turtles use nearshore coastal reefs along much of the Mozambican coastline as temporary or permanent foraging grounds (Chapter 3) (Bourjea et al., 2015). The green turtle population within the SWIO/WIO can be differentiated into four distinct genetic stocks. Sea turtles using Mozambican habitats are presumed to belong to the Northern or Southern Mozambican Channel (SMC or NMC) stocks (Bourjea et al., 2015). A regional scale assessment of the conservation status of green turtles in the SWIO does not exist (Seminoff 2004).

Loggerhead turtles (Caretta caretta)

The second-most abundant species within the SWIO region, and the most abundant nesting species in Mozambique, is the loggerhead sea turtle. Loggerhead turtles nest along most of Mozambique's southern coastline, and their most studied rookery within the SWIO occurs in the Trans-Frontier Conservation Area (TCA) between Mozambique and South Africa (Nel et al., 2013; Pereira et al., 2014a; Fernandes et al., 2016b). The Mozambican side of the TCA is a marine protected area (MPA) known as the Ponta Do Ouro Marine Partial Reserve (PPMR) (Fig. 1.3 - #20 on legend). The PPMR contains the majority of loggerhead nests in Mozambique (99.7% of all loggerhead nests, n = 752 nests 15/16 season; Fernandes et al., 2016a).

Nesting and foraging loggerhead turtles from Mozambique are part of a single SWIO genetic stock (Hamann et al., 2013; Fernandes 2015). Beyond the southern Mozambican nesting grounds, loggerheads also spend extended periods in what are thought to be foraging grounds in the Inhambane Province, southern Mozambique (Fig. 1.1) (Papi et al., 1997; Luschi et al., 2006) but their foraging and migration areas are poorly known. Based on population trends from the South African coast, the SWIO loggerhead population is listed as ‘Near Threatened’ on the IUCN Red List (Nel and Casale 2015), with an annual population of >590 nesting females (SWOT online turtle database; Kot et al., 2013; Mellet 2015). This population is regarded as stable and showing signs of increase (Nel et al., 2013).

Leatherback turtles (Dermochelys coriacea)

The leatherback turtle is the other species with nesting sites within the TCA. Most leatherback nests within Mozambique occur in this conservation area (95.6% of all leatherback nests, n = 46 nests 15/16 season) (Fernandes et al., 2016a). Satellite tracking of post-nesting South African leatherback turtles revealed dispersal to three foraging areas: South Atlantic Ocean, Western Indian Ocean and Mozambican Channel (Robinson et al., 2016; Robinson 2014). For individuals that remain within the WIO-Mozambican Channel, a northward post- nesting migration route along the edge of the continental shelf, typically remaining with 100 km of the coast, has been detected

(Robinson et al., 2016; Robinson 2014). These animals travel into the productive waters of Sofala Banks (in Sofala Province), where they are thought to exhibit some degree of residency. This area also supports Mozambique's largest commercial fishery, the shallow-water prawn trawl fishery (Gove et al., 2001; Brito 2012). Little is known about the spatio-temporal details of the leatherbacks occurrence within Mozambican waters. Only one Leatherback RMU occurs in the SWIO and has been regionally assessed as Critically Endangered (Wallace et al., 2013).

Hawksbill turtles (Eretmochelys imbricata)

One hawksbill RMU occurs within the SWIO, and one in the North Western Indian Ocean (NWIO). Hawksbills in Mozambican habitats are likely to belong to the SWIO stock, although no genetic studies have been completed to confirm this. Their conservation status has not undergone regional assessment (Mortimer and Donnelly 2008). Within Mozambique, scattered hawksbill nesting has been reported in the north of the country historically (zero nests reported in 14/15 and 15/16 seasons Fernandes et al., 2015 and 2016a). The extent of their use of offshore islands of Mozambique for nesting is not known. Reported nesting events from regularly monitored locations are restricted to Vamizi Island. Occasional sightings of hawksbill turtles occur within the study area at Tofo; however, they are infrequent and appear to be transient visitors (pers. obs.). It is presumed that hawksbill turtles use coastal reef systems in the Parabolic Dune and Coral Coasts coastal zones (see Fig.1.1 for distribution of coastal zones), however details of their spatio-temporal patterns or abundance within Mozambican waters are not available.

Olive ridley turtles (Lepidochelys olivacea)

The olive ridley is understudied throughout the SWIO. Only one RMU in the SWIO is known, and its conservation status has not been assessed (Abreu-Grobis and Plotkin 2008). The status of the olive ridley turtle within Mozambique is unknown and no nesting locations have been reported, although they may occur in the central and northern provinces (Louro et al., 2006).

Sea turtle legislation

All five species of sea turtles that frequent Mozambican waters are protected by national laws (Forests and Wildlife Regulation Decree 12/2002 of 6 June 2002; Louro et al., 2006). Mozambique is also a signatory to international treaties, such as the Convention on International Trade in Endangered Species (CITES, since 1981: CITES 2016), the Convention for Migratory Species (CMS 2016a) and the Memorandum of Understanding on the Conservation and Management of the Marine Turtles and their Habitats in the Indian Ocean and Southeast Asia (IOSEA-MoU, since 2008). However, enforcement of the current legislation is lacking, and almost non-existent outside of marine protected areas (Louro et al., 2006; Pereira et al., 2014).

Threats to turtles

Sea turtles (in all life history stages) face numerous anthropogenic threats globally and are considered conservation dependent (IUCN 2016). Threats in Mozambique have the capacity to negatively impact regional populations (Gove et al., 2001; Louro et al., 2006; Bourjea et al., 2008). Significant data gaps at the species level and a lack of quantification of threatening processes has precluded an accurate assessment of their impact. Threats identified within the region include illegal take (subsistence take or for illegal wildlife trade), bycatch (commercial and artisanal fisheries), plastic debris, climate change threats (temperature change, sea level rise, increased storm/cyclone activity), and coastal development (artificial lighting, habitat modification, nesting beach) (Louro et al., 2006; Costa et al., 2007).

Some threats, such as climate change, are broad in scale and pervasive, making it hard for specific management interventions to be identified. In contrast, threats such as bycatch or illegal take are generally spatially confined within a region and offer more scope for direct interventions. Illegal take from nesting beaches and nearshore waters has been hypothesised to be a significant problem within the region, particularly in Mozambique (and Madagascar) (Louro et al., 2006; IUCN 1996). This thesis is aimed at clarifying the data gaps relating to threats impacting sea turtles in Mozambique (Chapters 4 and 6), with a focus on the conservation impacts, spatial extent and drivers of illegal take (Chapter 4).

Socio-economic influence on biodiversity and conservation in Mozambique.

Mozambique is situated on the eastern African coast, with South Africa at the southern border and Tanzania to the north. The country claimed independence from the Portuguese in 1974. Shortly after, civil war broke out, which lasted for 16 years. Finally, in 1992, peace and democracy was officially established. The population is currently at 26 423 623 (INE 2016) and the country is currently ranked 180 out of 188 on the Human Development Index (HDI) (UNDP 2016). While peace has technically remained, political stability is highly variable and, as a foreign aid-dependent country, it is facing extreme financial and economic conditions after international donors and the international monetary fund (IMF) withdrew their support in the first half of 2016. Mozambique is becoming increasingly prone to natural disaster, regularly experiencing heavy flooding in the northern half of the country and severe droughts in the southern provinces (Wingqvist 2011). The country lacks agricultural capacity to supply its people domestically and relies on importing basic resources. The present political, financial and climate insecurity are reflected in its currency (metical MZN) which experienced severe declines in 2016, losing more than 70% of its value to South Africa's Rand and 50% of its value to the US dollar. It is likely that these external pressures will reduce the nation's overall capacity to thrive, improve and develop.

The civil war (1977-1992) significantly impacted biodiversity and conservation management in Mozambique (Hatton et al., 2001; Lindsey and Bento 2012). During the war an estimated 4 million people migrated from the interior of the country to coastal provinces, particularly in the south (Gervásio and Lopes 2003; Menezes 2009), leading to increased exploitation of marine animals for subsistence (Menezes 2009; Pereira et al., 2014b). Similarly, hunting of terrestrial mammals, birds and reptiles for bushmeat significantly increased during the civil war, resulting in localised extinctions and depauperate faunal populations (Hatton et al., 2001; Lindsey and Bento 2012). The overall impacts of the war and the movement of people to the coast on the use of natural resources is largely unquantified but is likely to be substantial.

Large areas of native vegetation, particularly in the southern coastal provinces, have been extensively cleared or modified (Sitoe et al., 2015) (Fig. 1.2). The majority of terrestrial mammal populations were extirpated or severely depleted during the 'hungry period' of the civil war (Ministry for the

Coordination of Environmental Affairs 1997). These factors (lack of flora and terrestrial fauna) have prevented the development of terrestrial ecotourism, and led to an ongoing wild protein shortage (Tibiriçá et al., 2011). This is likely to exacerbate the pressure on the coastal and marine environments (either through development for tourism or reliance on marine bushmeat for subsistence).

Economically, Mozambique depends on its coastal resources for commercial fisheries focused on shallow water shrimp and oceanic pelagics (e.g. tuna, bonito, billfish and sharks; Santana Alfonso 2006). Export of prawns/shrimp is one of the country’s most important sources of external revenue (MIPE 2013). In addition, small scale fisheries are economically important, contributing 91% of the total fisheries marine catch (IFAD 2011). Small scale fisheries have been reported as crucial for improving food security and reducing poverty (FAO 2007), and are expansive and diverse along the 2 700 km of coastline. Significant data gaps exist regarding the target catch and bycatch rates (Johnson 1992). Landings of industrial and small scale fisheries were thought to have peaked in the mid 1980’s and have subsequently declined (Jacquet et al., 2010).

Two-thirds of the Mozambican population rely on coastal resources for subsistence (UNEP 2015). However, almost all fisheries within Mozambique are thought to be overexploited and facing crisis due to declining productions and increasing operational costs (Pereira et al., 2014b; USAID 2010). Small scale fisheries and agriculture are important subsistence sources and the primary income sources for the majority of the population. In addition to these, tourism, harvest of tidal invertebrates and juvenile fish, trading, charcoal production, seaweed farming and aquaculture are thought to be important activities for community livelihoods and the local economy (Carvalho and Gell 1998; de Boer et al., 2002; Gervásio and Lopes 2003). Lack of access to basic needs, such as potable water, health care and education are common, particularly in rural communities (Virtanen 2005).

Outstanding marine biodiversity

In 2004 the World Wildlife Fund for Nature (WWF), a major international non-governmental conservation organisation (NGO), proposed the East African Marine Ecoregion (EAME), which includes Mozambique (EAME 2004). Mozambique has the longest coastline in the EAME and contains nine of 21 priority sites for conservation: the Mtwarae -Quirimbas Complex (a cross-border site between Tanzanian and Mozambique); Nacala-Mossuril; Primeiras and Segundas Archipelago; the Zambezi Delta System; Sofala Bay; Bazaruto Archipelago; Inhambane Bay; Inharrime Complex; and Maputo Bay - Machangulo Complex - Greater Saint Lucia Wetlands (another cross-border site between Mozambique and South Africa) (Refer to Fig. 1.3).

In addition to the EAME priority sites, the coast from Bazaruto Archipelago to Tofo has been proposed for consideration as a marine world heritage site, based on its outstanding marine biodiversity (Obura et al., 2012).

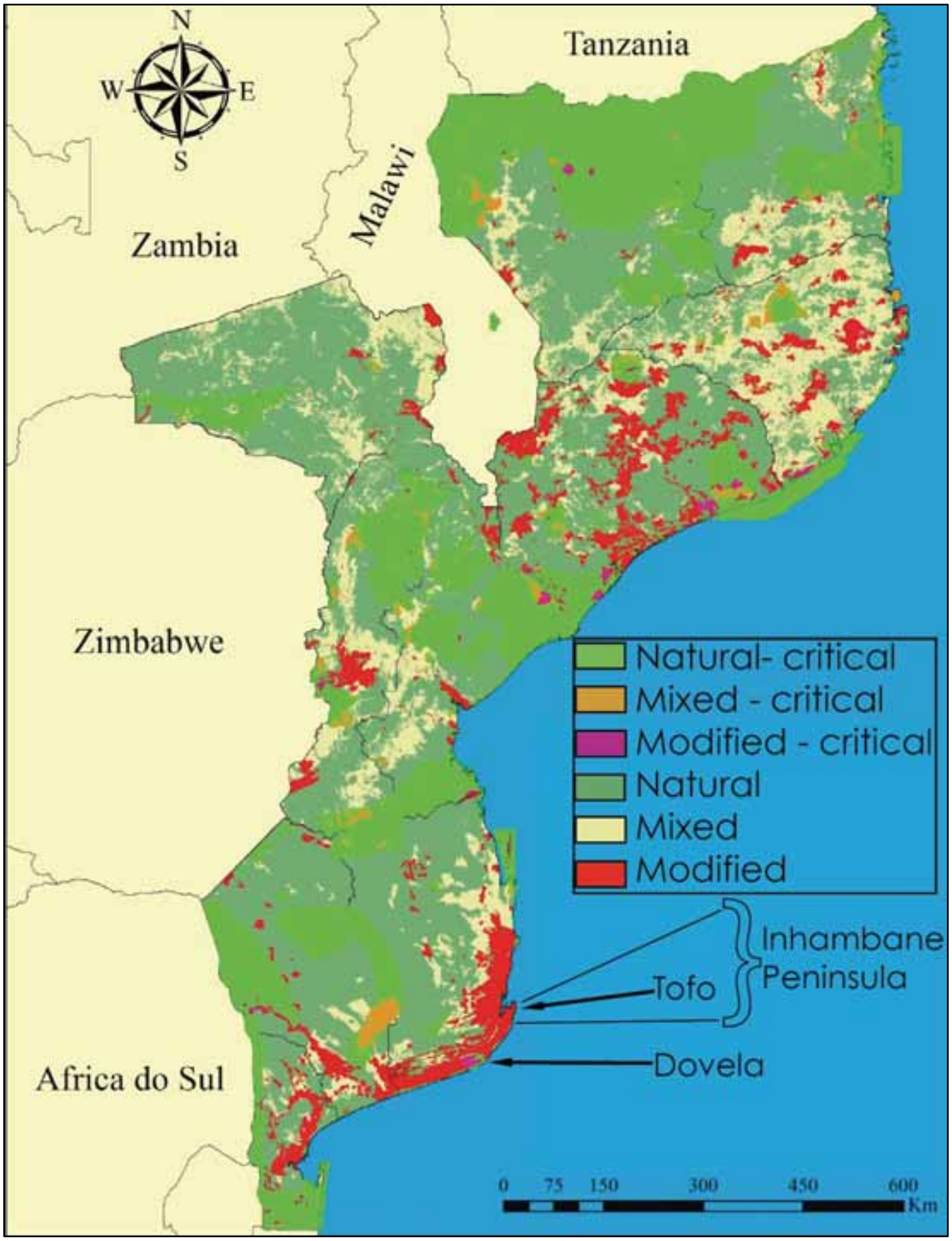


Fig. 1.2. Distribution of vegetation habitat types throughout Mozambique, showing proportions of critical terrestrial habitats with mixed, modified or natural status (Adapted and translated from Sitoe et al., 2015). The study region, Inhambane peninsula and two case study sites of Tofo and Dovela (natural critical and modified critical vegetation types) are shown.

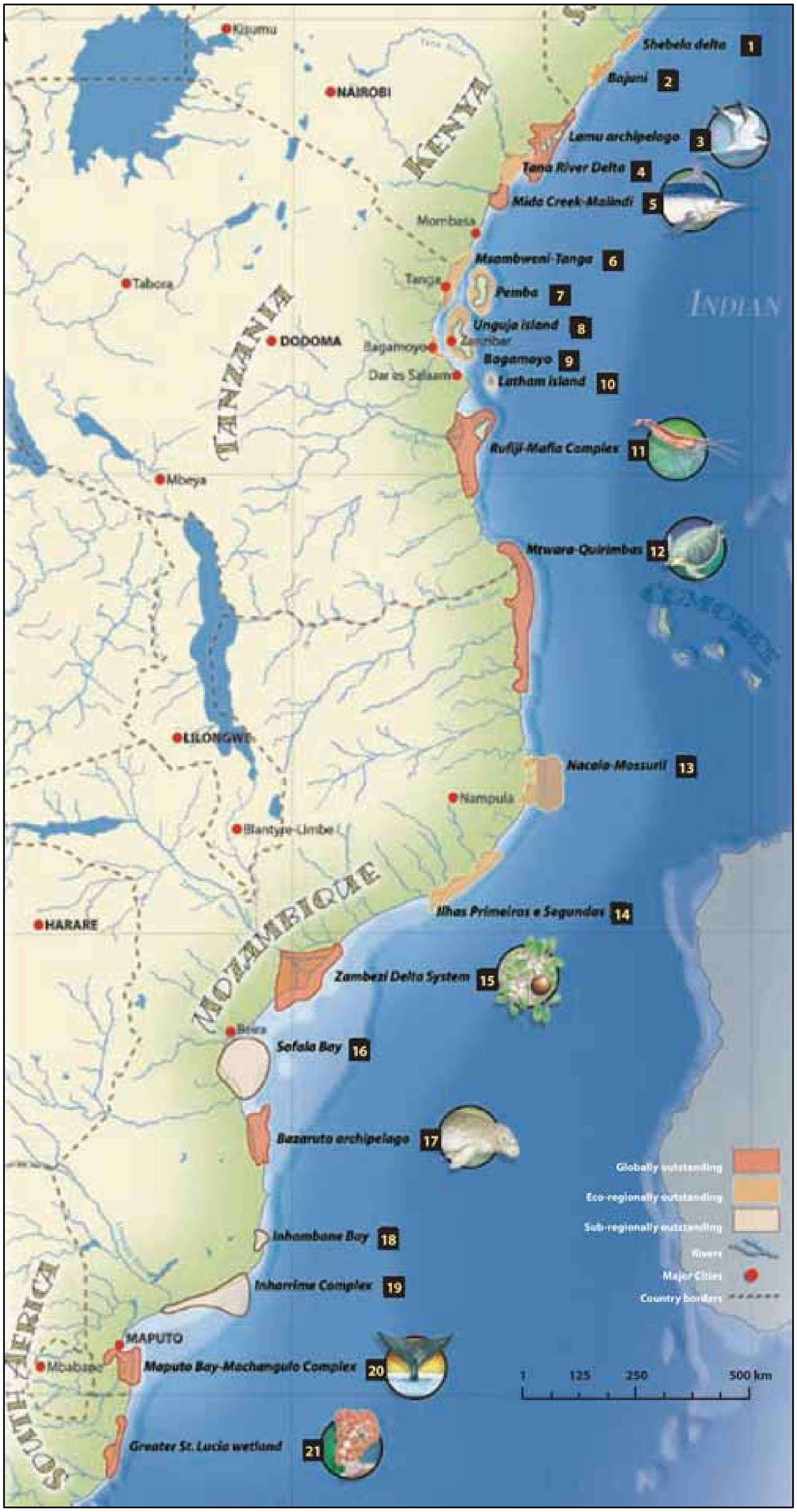

Shebela delta 1
Bajuni 2
Lamu archipelago 3
Tana River Delta 4
Mida Creek-Malindi 5
Msambweni-Tanga 6
Pemba 7
Unguja Island 8
Bagamoyo 9
Latham Island 10
Rufiji-Mafia Complex 11
Mtwara-Quirimbas 12
Nacala-Mossuril 13
Ilhas Primeiras e Segundas 14
Zambezi Delta System 15
Sofala Bay 16
Bazaruto archipelago 17
Inhambane Bay 18
Inharrime Complex 19
Maputo Bay-Machangulo Complex 20
Greater St. Lucia wetland 21
KENYA
TANZANIA
MOZAMBIQUE
SOUTH AFRICA
INDIAN
COMORES
Kisumu
NAIROBI
Mombasa
Tabora
Tanga
DODOMA
Bagamoyo
Zanzibar
Dar es Salaam
Mbeya
LILONGWE
Nampula
Blantyre-Limbe
HARARE
Beira
MAPUTO
Mbabane
Globally outstanding
Eco-regionally outstanding
Sub-regionally outstanding
Rivers
Major Cities
Country borders
1
125
250
500 km

Fig. 1.3. EAME priority sites within Mozambique and along the Eastern seaboard of Africa (EAME 2004).

Inhambane Province and study site, Praia do Tofo.

Inhambane Province in southern Mozambique is the largest coastal province in the country. Agriculture within the province is limited by poor soils and unfavourable climate, although economically important crops include cashew nuts, cassava, coconuts, citrus and maize. Tourism and ecotourism are important sectors of the provincial economy.

Praia do Tofo (Tofo) is a small tourism-focused village on the Inhambane Peninsula (Fig. 1.2). Tofo is situated 20 minutes away from a small international airport and 30 minutes away from the provincial capital city, Inhambane. A large saltwater estuarine system occurs just north of Tofo, known as Baia de Inhambane (Inhambane Bay). Inhambane Province occurs within the northern extent of a section of the coast categorised as the parabolic dune coast, where steep vegetated dunes (up to 120 m high) are often backed by salt lakes or closed salt lagoons (Hatton 1995; Momade and Achimo 2004). Where lagoons open to the ocean, they typically host extensive seagrass meadows and are fringed by mangrove areas. An example of such an ecosystem can be found in Inhambane Bay.

Tofo is a small and relatively undeveloped town dependent on tourism (diving, surfing, beaches). It is known as a marine megafauna hotspot and tourists flock to the area year-round for a chance to swim with or observe the ‘marine big 5’ (whale shark, manta rays, dolphins, humpback whales and sea turtles). Marine tourism in Tofo was established on the premise that it is one of few places globally where year-round populations of whale shark

(*Rhincodon typus*) and manta rays (*Manta birostris* and *M. alfredi*) occur (Tibiriçá et al., 2011). All three remain unprotected in Mozambique, and severe declines in sightings (Reef manta ray 88%, whale shark 79%) have been reported in the last decade (Pierce et al., 2010; Rohner et al., 2013).

Thesis objectives and Structure

Primary research aim and objectives

Given that information about the state of sea turtle populations (population size estimates, species composition, age class distribution, movements of animals into and out of the study area, residency, habitat use and preferences) was scarce or non-existent for Mozambique, two of my thesis chapters (2 and 3) were designed to supplement primary knowledge (i.e. form a baseline) enabling the relative impact of threats to the population to be quantified.

Most sea turtle research conducted globally has focused on nesting females, as the turtles are easily accessible to researchers when hauling themselves ashore. Unfortunately, the data obtained from studies on nesting turtles may not be representative of the population at large. In my primary study area, Inhambane Province of southern Mozambique, the density of nesting turtles is too low to adopt typical field methods. Therefore, my research adopted a number of different research techniques to increase knowledge on sea turtles in their foraging grounds and the anthropogenic impacts imposed upon them. Increasing the knowledge base of sea turtle species composition, abundance and spatio-temporal patterns from these Mozambican foraging grounds will be a valuable and useful contribution to informing the conservation, management and enforcement efforts in southern Mozambique. My major research aim is to

obtain baseline data on the population structure and distribution, and understand factors related to the take and use, of sea turtles within the Inhambane Province, Mozambique. The following research objectives were addressed (see box 1.1).

Viable baseline monitoring techniques & understanding the population structure of sea turtles:

1. *How can in-water turtle populations be monitored in a cost-effective way? (Chapter 2)*
2. *Can dive-based citizen science be utilised to understand the use of Mozambican coastal waters by sea turtles? (Chapter 3)*

Understanding threats:

3. *Can the extent of illegal take/use of sea turtles be quantified? Where is this take most likely to occur? (Chapter 4)*
4. *What are the main drivers and motives for illegal take and use of sea turtles? (Chapter 5)*
5. *What are the main threats to Mozambican sea turtles? (Chapter 6)*

Conservation & Management- gaps and challenges:

6. *What are the main limitations to conservation and management efforts? (Chapter 6)*

Box 1.1. Research questions for this thesis.

My research focuses on green and loggerhead turtles in Inhambane Province. They are the most common species in shallow coastal waters where anthropogenic threats are high. However, given that illegal take of sea turtles is not known to be species-specific, where data from encounters (in water or illegal take) were available for leatherback, hawksbill and olive ridley turtles, these have been included.

Thesis structure

This thesis follows the order of the objectives listed above. The thesis consists of seven chapters (Fig. 1.4). At the final submission of this thesis, Chapter 2 and 3 have been published and Chapter 6 is in revision. Chapters 4 and 5 are yet to be submitted to journals but this will follow the completion of this the thesis. Each chapter is presented as a stand-alone publication, with some modifications to ensure continuity and flow in thesis format. Where required, information has been repeated in several different chapters to enable each chapter to stand alone.

Chapter 1 provides a general introduction on sea turtle conservation biology within Mozambique. Here I present my rationale for research: investigating the impact of illegal take on sea turtles. I provide a brief overview on the current state of knowledge on Mozambican turtle populations and those of the greater South West Indian Ocean (SWIO) region, the current threats these populations face, and a summary of the significant data gaps. I also provide a concise summary on the socio-economics of Mozambique with a focus on artisanal small scale fisheries.

Chapter 2 aims to evaluate the effectiveness of recreational divers for monitoring sea turtles. I evaluate two citizen-science collected datasets collected from the study area, for usability in a population ecology context. This chapter 'sets the scene' for detailed analysis of spatial and temporal trends of coastal habitat use in sea turtles. *This chapter has been published at Endangered Species Research* as*:*

Williams JL., Pierce SJ., Fuentes MMPB., Hamann M. (2015) Effectiveness of recreational divers for monitoring sea turtle populations. *Endangered Species Research* 26:209–219.Doi:10.3354/esr00647

Chapter 3 builds upon the findings in Chapter 2. I modified the field collection methods and data recording to strengthen the quality of information provided by citizen-science. This chapter expands on the preliminary results on sea turtle sightings, species composition and size ranges initially obtained from citizen-scientist dive logs. Here I use photo-ID encounters, a comprehensive dive log and geospatial records to evaluate the temporal, spatial and environmental predictors of sea turtles. I also examine the habitat preferences and residency of green and loggerhead turtles and postulate a high rate of overlap in the area utilised by these species and SSF. The variations in age classes, habitat use and movements between species are likely to lead to disproportionate impact(s)on resident individuals. This chapter has been published in *Frontiers in Marine Science as:*

Williams JL., Pierce SJ., Rohner CA., Fuentes MMPB., Hamann (in revision: Dec 2016) Use of coastal reef habitats by green and loggerhead turtles in southern Mozambique. *Frontiers in Marine Science (3) 288: 1-16*.

Chapter 4 is the first comprehensive quantitative assessment of illegal take of sea turtles within southern Mozambique. I combine the results from beach transects with literature records from outside of Inhambane Province to assess the quantity, spatial extent and temporal scale of illegal take. I also examine the overlap between sea turtles in coastal waters with records of SSF and evaluate areas of high risk.

Chapter 5 investigates the motives and drivers for the illegal take and use of sea turtles within southern Mozambique. I use semi-structured interviews to document the socio-economics of small scale fisheries between two coastal areas, one relatively inaccessible (Dovela) and the other a popular tourism town (Tofo). I examine the similarities and differences in SSF between the two areas and the variations in behaviour of turtle fishers. The motives and drivers for illegal take are discussed within the context of the larger-scale problem of bushmeat hunting.

Chapter 6 I use the Analytical Hierarchy Process to quantitatively rank and prioritise experts opinions on the significant threats to turtles within the region. I make recommendations for advancing and enhancing current conservation and management efforts under limiting conditions (funding, resources, capacity, political support), This chapter presents a framework/process for conservation managers in developing countries to quantitatively evaluate and prioritise current states of knowledge or data gaps. *This chapter is presently in revision for publication to Aquatic Conservation: Marine and Freshwater Ecosystems* as:

Williams JL., Pierce SJ., Hamann M., Fuentes MMPB. (in review) Using expert opinion to fill the gaps on sea turtle threats: A case study in a data-poor context. *Aquatic Conservation: Marine and Freshwater Ecosystems.*

Finally, in **Chapter 7**, I summarise the findings from my five data chapters, and discuss how they can contribute to the ecology, conservation and management of sea turtles within Mozambique and elsewhere. I also discuss challenges that were faced during my investigation, and provide recommendations for future studies.

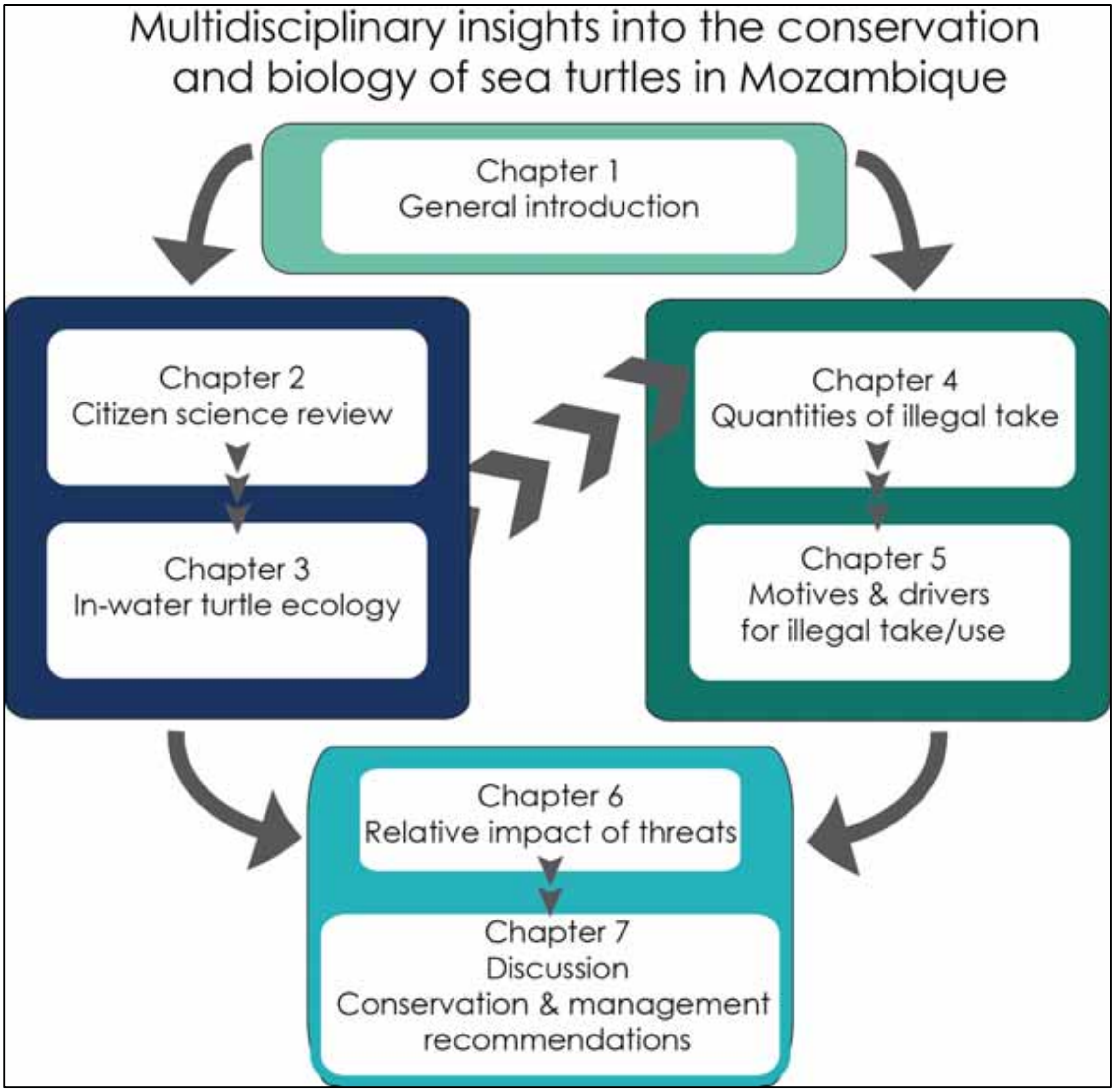


Fig. 1.4. Thesis structure outline

Chapter 2

Effectiveness of recreational divers for monitoring sea turtle populations

The knowledge gaps in basic population ecology and spatio-temporal distributions of sea turtle populations using Mozambican waters were identified in Chapter 1, however these data gaps could be potentially answered with data collected through citizen-science. This chapter presents a review of two different types of citizen science collected data to evaluate the suitability of using such to form a simple/preliminary baseline for in-water monitoring of sea turtle populations. In this chapter, I present the strengths and weaknesses of such datasets and make suggestions for strengthening and improving future citizen-science monitoring programs. This review, and the subsequent changes made to monitoring and reporting procedures of a recreational diver citizen-science project formed the basis of the dive log and photo-identification program used in Chapter 3 to evaluate coastal habitat use.

Published manuscript:

Williams JL., Pierce SJ., Fuentes MMPB., Hamann M. (2015) Effectiveness of recreational divers for monitoring sea turtle populations. *Endangered Species Research* 26:209–219.Doi:10.3354/esr00647
http://www.int-res.com/abstracts/esr/v26/n3/p209-219/

Abstract

Five sea turtle species, all globally threatened, are found in southern Mozambican waters. Illegal hunting of foraging turtles, nest raiding and modification of coastal habitat are assumed to affect local sea turtle populations, but a lack of capacity and resource constraints hamper monitoring and compliance activities. Enlisting the recreational SCUBA diving community to report sea turtle sightings is a potential solution for population monitoring. The effectiveness of recreational divers as data collectors was tested through the review of 2 approaches: the use of a routine dive logbook with sightings, and data from a dedicated survey. These approaches provided 37 consecutive months of data between 2008 and 2011 from dive sites in Inhambane Province, Mozambique. A total of 317 sightings of loggerhead *Caretta caretta*, green *Chelonia mydas*, hawksbill *Eretmochelys imbricata* and unidentified turtle species were reported from 918 dives. While the dedicated survey collected more detailed behavioural data (e.g. response to divers and feeding behaviour), independent logbook records provided a more robust data set for analysis of sighting trends. Useful data on sea turtle species composition, size and distribution were obtained from both approaches, although there were concerns with regard to species identification and size estimates. With refined methodology, particularly the incorporation of photographic verification of species identification, reports from divers can provide cost-effective and useful data for monitoring foraging turtle populations.

Introduction

An increasing number of research programmes incorporate non-specialist members of the public as ‘citizen scientists’, both as an educational tool and as a cost effective monitoring strategy (Bhattacharjee 2005, Bonney et al., 2009; Crall et al., 2011). In the marine realm, volunteer recreational divers have been involved in collection of data for biodiversity assessments and coral reef fish (Darwall and Dulvy 1996; Hodgson 1999; Pattengill-Semmens and Semmens 2003) and flora abundance surveys (Chou 1994; Schmitt and Sullivan 1996). In addition to these broadly scoped programmes, volunteer scuba divers are also involved in focal species programmes focused on sea horses (Goffredo et al., 2004), sea turtles (Bell et al., 2008b) and elasmobranchs (Hussey et al., 2011; Ward-Paige and Lotze 2011). Although such data collection programmes are generally designed to test specific hypotheses or undertake routine monitoring, a key tenet is that participants are not required to have formal training in scientific survey techniques.

By accepting the limitations of such a tenet, the overwhelmingly appealing aspects of adopting a citizen-science programme can be realised. Such benefits include low cost and a potentially large unpaid work force, allowing for monitoring over large geographic areas or temporal periods (Mumby et al., 1995; Teleki 2012). Additionally, citizen science programmes can be used as education and outreach tools to promote conservation objectives and even to engage potential funders or fund specialist research projects (Gouveia et al., 2004). The success of citizen-science projects, as measured through their outputs or scientific applications, has been varied (Darwall and Dulvy 1996, Van Strien et al., 2013), but has increased over time.

However, because some volunteer-based efforts are not developed with the aim of producing publishable data in mind (Paulos 2009) or, alternatively, do not result in data of suitable quality, the value of such programmes to conservation and management has been contested

(Halusky et al., 1994; Mumby et al., 1995; Darwall and Dulvy 1996). Debates centre around aspects of the inherent shortcomings of citizen science with a focus on the effectiveness and adequacy of training. One common deficiency of citizen science projects is a lack of recognition by participants of potential sources of error and associated corrective actions, due to their lack of familiarity with experimental design (Paulos 2009). Citizen scientists have also been criticised for overestimating abundance and species diversity (Foster-Smith and Evans 2003; Uychiaoco et al., 2005), and failing to fully document observations (Roxburgh 2000; Barrett et al., 2002) or record factors such as effort (Halusky et al., 1994; Lynch et al., 2004). There have also been concerns on the reliability of taxa identification below family level (Halusky et al., 1994; Mumby et al., 1995). Comprehending both strengths and weaknesses of citizen science is essential for successfully utilising this technique (Conrad and Hilchey 2011). To achieve effective research outcomes, the citizen science programme must be designed to account for the capacity of its volunteer collectors and the skills required to implement its data collection method (Shirk et al., 2012; Van Strien et al., 2013). In the present chapter I evaluate the utility of data collected by volunteers undertaking an in-water sea turtle monitoring project. I make recommendations to improve the design of such projects to maximise scientific value.

Monitoring of nesting sea turtles has traditionally used a large volunteer workforce (Ellis 2003). There are some long-running and well-recognised turtle projects that are based on a model that uses citizen scientists to collect most or all of their data, for example, at Tortuguero in Costa Rica (Campbell and Smith 2006) and Mon Repos in Australia (Wilson and Tisdell 2001). In most cases, such field-based marine turtle research projects are overseen by trained researchers and implemented by trained volunteers or staff, as in programs in Florida and North Carolina, USA (Bradford and Israel 2004; Cornwell and Campbell 2011), and generally include quality checks on the data. Citizen science is often considered a cost-effective tool for ensuring sufficient participants to complete resource- intensive monitoring programmes, such as comprehensive nesting beach censuses (Eckert 1999; Silvertown 2009; Landry and Taggart 2010), that would not otherwise be economically or logistically feasible.

The relative ease of land-based, as opposed to ocean-based surveys means that sea turtle population estimates tend to be based on nesting surveys rather than knowledge of total population size (Bjorndal 1999; Sims et al., 2008). In-water monitoring programmes have frequently adopted physical capture techniques, such as tangle netting (Seminoff et al., 2002; Eaton et al., 2008) and direct capture (rodeo) (Limpus and Reed 1985; Ehrhart and Ogren 1999) to monitor populations stocks. Some in-water sea turtle monitoring projects have used volunteers or recreational divers for data collection, but their application is often limited because these specific projects have typically been equipment intensive and require specialist training and physical skills (e.g. SCUBA, free diving and advanced animal handling skills). Although the opportunity to view sea turtles is often acknowledged as a tourist attraction on coral reefs (Schofield et al., 2006, Eaton et al., 2008), a scarce number of projects have explored this as a potential solution for collecting information and there are fewer documented projects based on non-invasive in-water citizen science for monitoring foraging turtles (e.g. Hickerson 2000; Houmeau 2007; Bell et al., 2008b).

Five sea turtle species live and nest along Mozambique's 2700 km coastline: loggerhead (*Caretta caretta)*, green (*Chelonia mydas)*, hawksbill

(*Eretmochelys imbricata)*, leatherback (*Dermochelys coriacea)* and olive ridley turtles (*Lepidochelys olivacea)* (Louro et al., 2006). All sea turtles in Mozambique face increasing threats from fishing (including gill-netting, beach seining and trawling), direct take (fishing for sustenance and/or traditional take) and coastal habitat modification (artificial lighting and industrial developments) (Louro et al., 2006; Costa et al., 2007). Data on their distribution, migration and nesting areas in the country are scarce and restricted to a few locations (Costa et al., 2007). Inhambane Province, in southern Mozambique, is an emerging marine tourism destination (Pierce et al., 2010; Tibiriçá et al., 2011) and has been proposed as a potential Marine World Heritage site based on its outstanding marine wildlife (Obura et al., 2012). However, this region also has the highest recorded levels of turtle mortality in Mozambique (Pereira et al., 2010), despite all turtle species having been legally protected from consumptive use since 1965 (Pereira et al., 2010). There is a need for baseline data to effectively manage Mozambique's turtle populations, which currently cannot be achieved through conventional means due to limited resources. The citizen science approach may be a solution to this issue.

Conscientious, long-term record keeping by recreational divers has been shown to have considerable scientific value (Goffredo et al., 2010; Ward-Paige and Lotze 2011; Jaine et al., 2012), particularly when there are reliable records of the presence and absence of the focal species coupled with environmental data (Goffredo et al., 2004; Hussey et al., 2011; Ward-Paige et al., 2011). Divers can facilitate continuous temporal monitoring of large areas where resources and either traditional academic or government research interest are low (Goffredo et al., 2010; Lorenzo et al., 2011). Increasingly, scientists are utilising these citizen science records and personal logbooks to assess long-term trends (e.g. Lloyd et al., 2012; Jaine et al., 2012) and an increasing number of historical data sets are being recognised as a source of high quality data (Miller-Rushing et al., 2012).

Mozambique, where there are few resources available for monitoring, there is a long and remote coastline and there is limited knowledge of species abundance and distribution, presents a challenge for conservation managers. Specifically, low rates of contemporary nesting and thus, limited opportunity to sample on nesting beaches, creates a challenge for managers to assess the impacts and scale of direct take of nests and nesting turtles. Instead, I assess foraging sea turtle populations in an understudied region of Mozambique by evaluating data collected from two different citizen science initiated monitoring programmes: (1) logbook records from a single dive operator, and (2) a dedicated survey of sea turtle sightings recorded by multiple staff from different dive operators and paying volunteers from a local conservation organisation. Two such pre-existing citizen science data sets were available for the purpose of comparing strategies to investigate whether either could produce usable data. The aim was to evaluate the results, identify issues associated with using volunteer participants and refine protocols for future studies that could benefit from a similar approach. My secondary objective was to provide the first information from in-water observations of species composition, abundance and spatio-temporal patterns of sea turtle presence from Mozambique.

Materials and Methods

Data collection

I was provided access to two data sets from the Tofo dive tourism industry to review their potential scientific value for in-water sea turtle monitoring. First, there was a dive logbook/register independently established and collected by one dive centre, where the megafauna species sighted on every dive were recorded (e.g. bottlenose dolphin, humpback whale, white tip reef shark, reef and giant manta rays), regardless of presence/absence of turtles (logbook). Second, from 4 other dive centres, there was a turtle sightings survey, where divers specifically reported the presence of a turtle during a dive (dedicated survey), which was initiated by a marine volunteer project. Whilst the dedicated survey was intended for scientific use, the logbook was recorded without a specific purpose, or at least not originally intended for scientific application.

The logbook data set covered 653 dives conducted between 19 March 2008 and 28 October 2009, and represented the majority of diving effort conducted by this dive centre (similar to Lynch et al., 2004). All staff members were involved in the data recording process. For analysis, turtle sightings were reported as a daily binary presence/absence at each dive site to avoid potential bias from individual turtles being double-counted during a single dive, or by different groups on a single day. Species and dive site were recorded, and other parameters including depth, total dive time, current strength and visibility were also reported for most dives.

Project coordinators of a marine volunteer conservation organisation initiated a dedicated survey for sea turtle sightings that took place between 2009 and 2011, using a survey protocol adapted from Bell et al., (2008b). Surveys were designed to record sea turtle sightings on a daily basis. Following a voluntary agreement by four dive centres (notated as dive center A, B, C and D) to participate in the monitoring programme, a briefing was provided to give instruction on methodology and data capture. A briefing on turtle species identification by the project coordinator of the marine conservation programme was provided to participating staff at each dive operation. Materials, such as dichotomous keys, along with charts and information posters to assist with species identification, were also provided. Participants were encouraged to provide photographs to validate species identification. Criteria on the survey forms included date, time, location, species, behaviour and environmental characteristics (depth, water temperature and visibility). Dive centre D hosted paying volunteers from a marine conservation programme, and these volunteers participated in the dedicated survey programme. At each dive centre, one person from each trip, most frequently a divemaster, divemaster trainee or marine volunteer (at dive centre D), filled in the dedicated survey form. Dedicated survey forms were completed in accordance with group consensus of the paying volunteers (from dive centre D) or dive staff present on the dive.

Site description

All data were collected from reefs close to Tofo Beach (Praia do Tofo) (−23.51° S, 35.23° E), a small seaside resort town situated in Inhambane Province, Mozambique, about 400 km northeast of the nation’s capital, Maputo (Fig. 2.1). Survey reefs were located along a 40 km stretch of coast from 500 m to 15 km offshore. These reef habitats are rocky with low hard coral diversity. The depth of surveyed reefs ranged from 11 to 30 m. Ocean conditions are dynamic, with underwater horizontal visibility varying from 5 to 30 m (Tibiriçá et al., 2011) and water temperature varying seasonally from a high of 30°C during summer months (Dec−Mar) to 16°C during the winter (Jul−Sep) (Rohner et al., 2013). Current strength is also variable, with stronger currents potentially affecting the search ability and coverage of divers. When weather conditions with a Beaufort sea-state of 4 or above (and swells of 2.5 m or above) were present, diving was prohibited for safety reasons. Cyclones occasionally occur over summer months and lead to periods where diving is not possible.

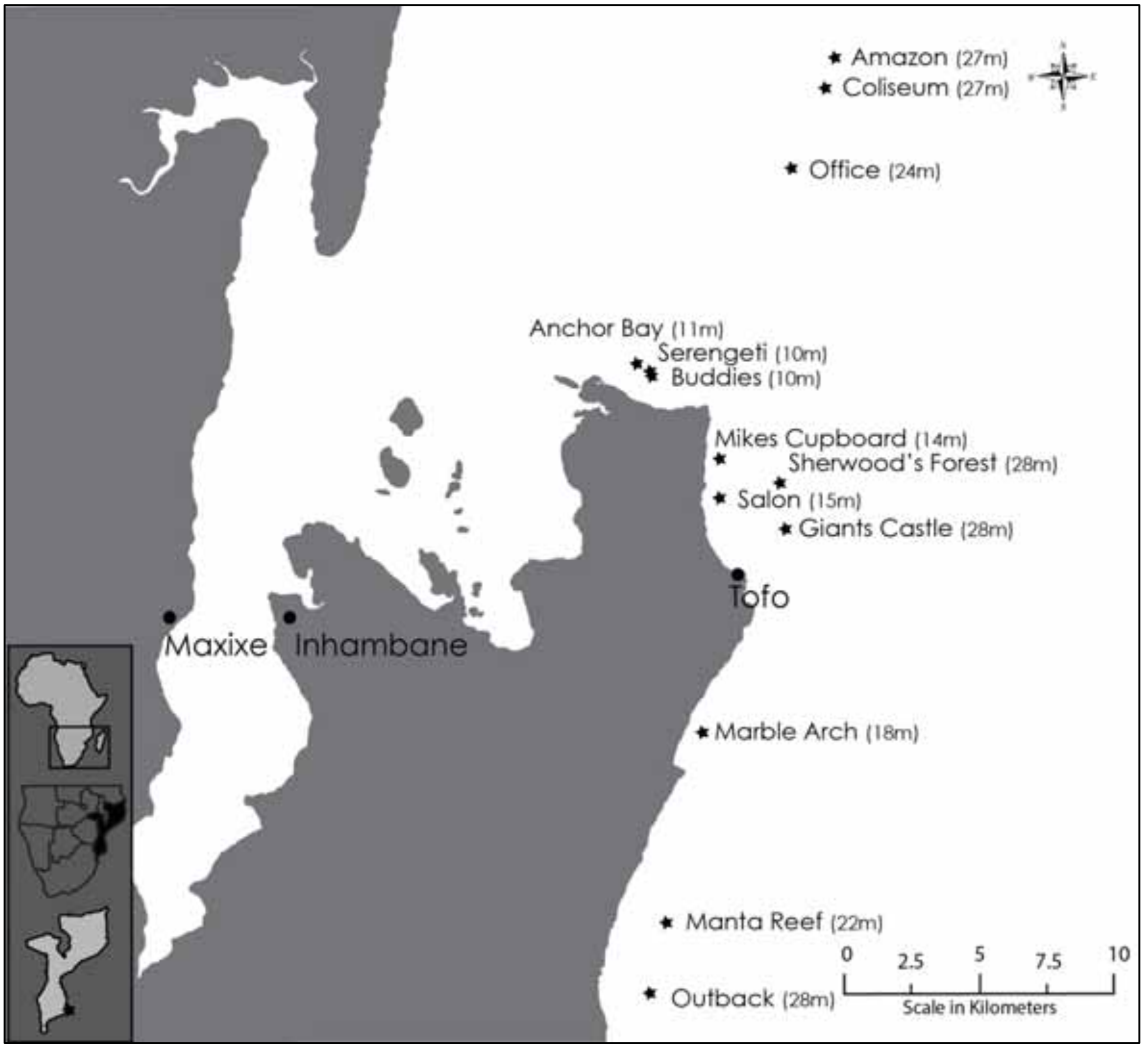


Fig. 2.1. Study site (Tofo Beach, Mozambique) and surveyed dive sites, with average depth (m) in parentheses.

Data validation and analysis

To avoid possible data duplication within a day, or between dive groups at 1 site, only 1 record per species per day at a specific site was used in analyses. Similarly, to avoid the possibility of double-counting an individual turtle seen at different times during the same dive, I treated data as presence/absence rather than a count of individual turtles. On days with multiple encounters, only the first record of the day was included in analysis.

During the 16-mo sampling period this resulted in elimination of 27 records across 24 sampling days (2 animals sighted per day, n = 22; 3 animals sighted, n = 1; 4 animals sighted, n = 1). This also resulted in ancillary data, such as sizes and behaviour, which were discarded through this process. Minimum categories required from either the logbook or dedicated survey included date, dive site and animals sighted. Although sightings (n = 24) of leatherback turtles (*Dermochelys coriacea)* were recorded in the data set, these records were not considered in analyses as they were always of animals sighted at the sea surface while boats were in transit, rather than at specific dive sites.

Where possible, mean dive times and depth were calculated for each site to provide a representative measure of effort. Because dive times were recorded in the logbook data set, the probability of encountering a turtle during a dive (turtle sightings per hour) could be calculated. Differences in the characteristics of each data set meant that they could not be combined for analysis of annual and seasonal sighting trends, so intra-data set analyses were conducted to evaluate the accuracy and utility of results. Estimates exceeding 1.2 m for loggerhead, 1.4 m for green and 0.9 m for hawksbill turtles were classified as biologically improbable (Van Buskirk and Crowder 1994). All length estimates were included in the analysis to demonstrate accuracy; however, it was not possible to calculate mean carapace length as observers visually estimated lengths. Inter-annual and seasonal trends could not be examined using the consecutive data sets together due to positive sighting bias in the dedicated surveys; instead, they were considered independently.

Results

Logbook

Fifty-two turtle sightings were recorded during 653 dives between 19 March 2008 and 28 October 2009, equating to a sighting rate of 8.1%. A mean turtle- sighting rate of 0.15 turtles h^{-1} was calculated from the total dive effort (497.89 diving hours). The majority of sightings (67.4%, n = 35) were not classified to species. For identified sightings, loggerhead turtles were the most frequently observed (n = 10), followed by green (n = 4) and hawksbill turtles (n = 3; Table 2.1). Estimates of carapace length (CL) were not recorded in the logbook data set.

Table 2.1. Response rates per data collection criteria according to dataset, Logbook (n = 720) and Dedicated Surveys (n = 330).

Category	Logbook response rate (%)	Dedicated Survey response rate (%)
Date	100% (n = 720)	98% (n = 330)
Total Dive Time	21% (n=155)	-
Time of Encounter	-	94% (n = 313)
Site	97% (n = 701)	100% (n = 334)
GPS	-	1.5% (n = 5)
Species	10% (n = 73)	97% (n = 325)
Size	-	76% (n = 248)
Sex	-	6% (n = 21)
Behaviour	-	87% (n = 291)
Seas (m)	-	17% (n = 58)
Swell (m)	-	16% (n = 56)
Visibility (m)	15% (n = 105)	61% (n = 202)

Temperature (^{o} C)	11% (n = 79)	66% (n = 223)
Depth (m)	21% (n = 155)	29% (n = 98)
Number of Divers in the water	23% (n = 78)	-
Encounter duration (min)	-	26% (n = 87)
Avoidance (Y/N?)	-	83% (n = 280)

Of 720 dives recorded in the logbook data set, 653 (~91 %) entries were sufficiently complete (minimum recording standard of date, dive site and animals sighted) for use in analyses. The response rate per category was not consistent across the 2 data sets (Table 2.2). Response rates for date, site and depth were comparable between logbook and dedicated survey methodologies, but there was lower reporting of species, temperature and visibility categories in the logbook data set (Table 2.2).

Table 2.2. Summary of reported turtle sightings by species and dataset from Tofo Beach. Data is summarised to avoid duplicate sightings (only one turtle per day for each site dived was included). Sightings for each dataset were reported between 19/03/08 - 28/10/09 in the Logbook and 13/12/09 - 22/03/11 in the Dedicated Surveys.

Species	*C. caretta*	*C. mydas*	*E. imbricata*	Unknown	Total
Dataset 1: Logbook	10	4	3	35	52
Dataset 2: Dedicated Survey	109	91	59	6	265
Total	119	95	62	41	317

Dedicated surveys

A total of 265 turtles were recorded across a 16-mo sampling period between 13 December 2009 and 22 March 2011. Contribution of data was not consistent between the 4 dive centres participating in the dedicated surveys (A = 49, B = 64, C = 43, D = 109). It was not possible to use the turtle sighting and dive records to quantify effort because overall dive effort per centre was not collected, and one dive centre (D) was a key supplier in the data collection process. Although the dedicated survey record sheet focused on positive sightings of turtles, divers and dive centres were encouraged by volunteer project coordinators to record dives where turtles were absent. Despite the encouragement, no records were submitted of zero sightings, leading to an artificially high 100% sighting rate from this data set. The response rate of surveys completed with enough information to include in analysis was lower (n = 265, ~ 80%) from the dedicated survey forms (n = 334) than from the logbook (~ 91%). There were 9 additional information categories requested in the dedicated survey forms compared to the 8 core categories in the logbook (Table 2.2).

Data collectors assigned 97% of sighting records to a species. The most abundant species recorded in this data set were loggerhead, followed by green and hawksbill (Table 2.1). Of 265 sightings, CL was provided in 70.94% (n = 188) of records. Biologically implausible overestimates were apparent in 11.7% (n = 22) of records, with loggerheads being the species most likely to have overestimated CL (n = 16). A mixed size structure was evident (Fig. 2.2). Irrespective of species, all individuals exceeded 40 cm CL, and the most common size bin of turtles recorded was for estimated CL of 71 to 100 cm. The largest variation in size of estimated CL was in green turtles (40 to 110 cm; Fig. 2.2A).

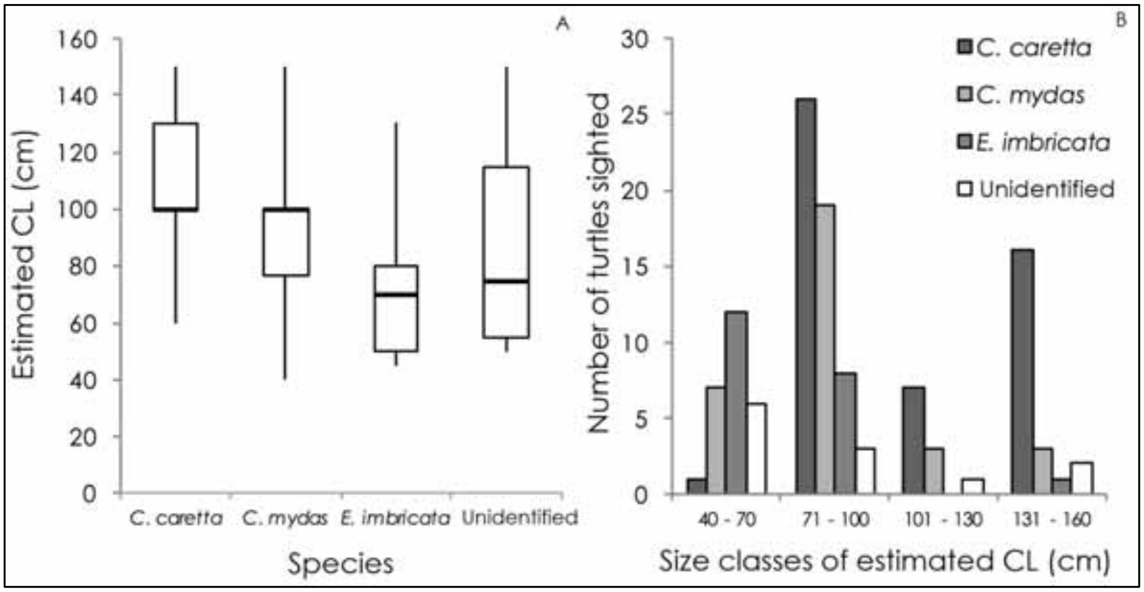
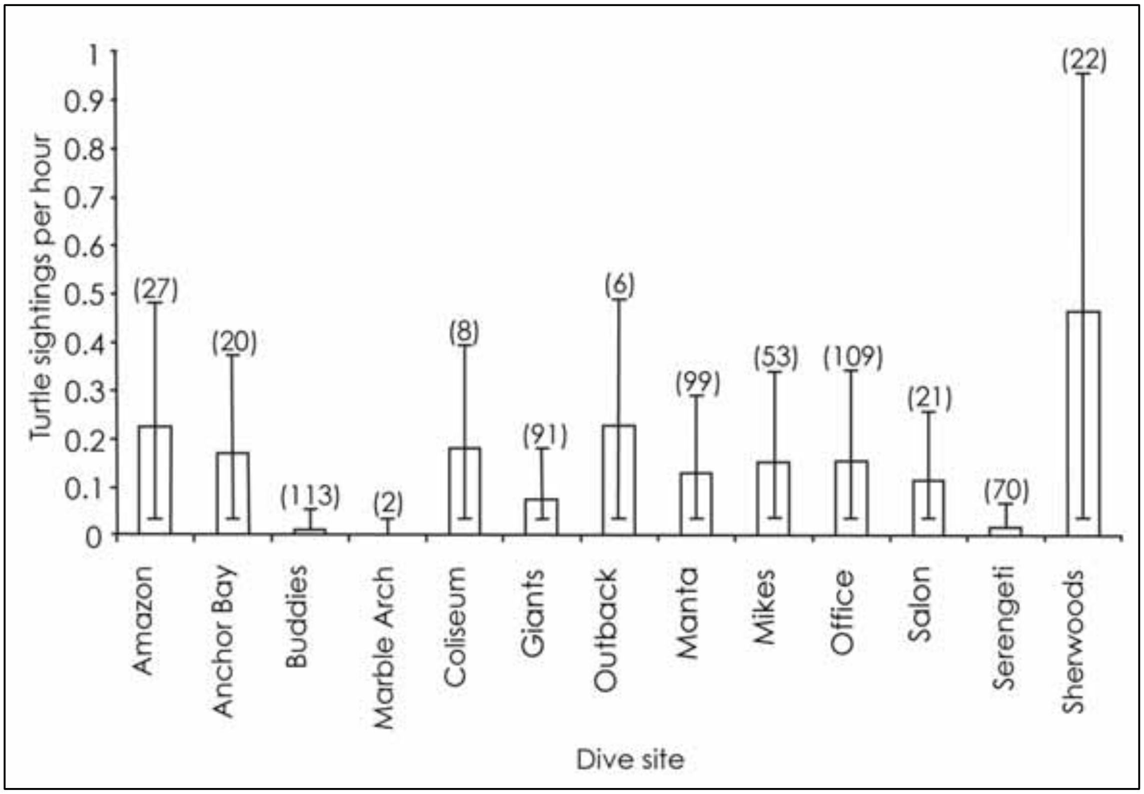


Fig. 2.2. Size of turtles sighted in the course of the dedicated surveys (n = 115) for *C. caretta*, *C. mydas*, *Eretmochelys imbricata* and unidentified animals. A) Linear descriptive statistics from dedicated survey data showing the range and spread of estimated carapace length (CL) data between the 25th and 75th percentiles, with bold line representing the median. B) Count and distribution of estimated turtle CL according to species, including estimates suspected to exceed biological maximums (n = 22).

Comparison between logbook and dedicated surveys

Data from both data sets indicated that daily turtle sightings varied significantly among dive sites (2-tailed *t*-test, $t = 51.33$, df = 51, $p < 0.001$). The highest sighting rates were recorded at the deeper dive sites, including Sherwood's Forest (28 m; 0.46 ± 0.16 turtles h^{-1}), Hogwarts (28 m; 0.22 ± 0.22 turtles h^{-1}) and Amazon (27 m; 0.22 ± 0.10 turtles h^{-1}) (Fig. 2.3). In addition to sightings, the frequency with which dive centres visited the high-density turtle sites (pooled for Amazon, Hogwarts and Sherwood's) also varied from



a minimum of 9.37% (of all records logged) by dive centre B to a maximum of 23.85% by dive centre D.

Fig. 2.3. Turtle sightings per hour per dive site (mean ± SE) from the logbook data set. Total numbers of dives per site (n) are displayed above the error bars

Discussion

Using recreational divers for monitoring sea turtles

The study demonstrated that useful data for monitoring foraging turtles, including detected abundance, species composition, sightings distribution and population structure, can be obtained from re- creational divers. However, in future studies, the importance of careful experimental design and meticulous reporting procedures should be emphasised. It is clear from the data sets examined that ad hoc implementation and reporting by casual observers diminished the scientific value of the data sets. The data are valuable for providing basic population structure, species composition and turtle sighting rates, and although precise morphometrics, such as CL, were not as reliable, they could be easily improved for future studies. If dedicated surveys were reported more regularly and coupled with photo-identification records, these data would allow for examination of seasonality, individual site residency, population models and long-term sighting trends. With some modifications to survey structure, training and reporting, the involvement of the diving community could broadly benefit research on foraging sea turtles. Specifically, in Mozambique, the information on basic population structure and species composition could form a baseline to inform and improve local management of turtles. Both data collection strategies had their apparent strengths and I suggest a combination of the two methods to be implemented at this project site to maximise scientific value of the data sets. Based on these experiences, a long-term dive log, including pre-established reporting criteria should be adopted. A live, online form such as those generated by google drive is a practical way to collect this information. Use of the mandatory data fields feature prohibits the user submitting the form until all the criteria have been filled in (examples of the live dive log forms can be found in the appendices 2.1 and 2.2). Such records, coupled with frequent participant training and quality control checks, are likely to form the basis of knowledge for foraging sea turtle research in Mozambique. This method is a valid, low-cost option which could be applied throughout the South West Indian Ocean (SWIO) for monitoring regional populations and could potentially be used as a tool to engage further inter-regional collaboration between interested sea turtle conservation stakeholders.

Insights into the species composition of turtles in Mozambique

Species composition was consistent between data sets, with loggerhead sea turtles the most abundant, followed by green turtles. Sightings of hawksbill, leatherback and olive ridley turtles were reported less frequently, rarely and not at all, respectively. Southern Mozambique is an important nesting ground for loggerhead (Gove and Magane 1995) and leatherback sea turtles (Louro et al., 2006). The observed species composition ratios are compatible with observed trends (pers. obs.) and suggest that volunteers have a reasonable ability to identify turtles to species level. The abundance of loggerhead sea turtles is consistent with them being the predominant nesting species in the study area (Gove and Magane 1995). The relatively high ratio of green sea turtles suggests that the study area is an important foraging habitat for the species, many individuals which nest in northern Mozambique and in limited numbers further north in Inhambane Province (Bazaruto Archipelago) (Hughes 1971; Costa et al., 2007; Garnier et al., 2012). Additionally, approximately 500 km to the east of the study site, the island of Europa hosts the largest documented green turtle rookery in the SWIO. Although the Madagascan coast is thought to be the primary foraging area for Europa green turtles, it is likely that some of the turtles seen in Mozambique are part of this stock, which still has to be investigated in future studies (Lauret-Stepler et al., 2007).

The CL data were sufficient to indicate basic population structure. The varied size data reported suggest a mixed age structure of the Tofo Beach population. Estimates of CL were recorded in 45% of turtle sightings from the dedicated survey data set, with most individuals (irrespective of species) estimated to be 71–100 cm CL, suggesting that the majority of turtles present are large immature or adult individuals. However, around 12% of estimates by divers were larger than the recorded maximum sizes for these species, particularly for loggerheads, for which 73% of estimates were biologically unlikely. Overestimates may be attributed to the magnifying effect of water in combination with limited training and experience. Consistent over-estimation of CL may lead to misinterpretation in the population size structure. I strongly suggest that this data be cautiously interpreted and that improvements to CL estimation process are sought. To overcome error in CL estimates, a subsample of turtles at each site could be measured and then validated by laser photogrammetry (Marshall et al., 2011; Rohner et al., 2011). Alternatively, participants could complete a training programme using objects of known size to improve accuracy of length estimates (Darwall and Dulvy 1996; Houghton et al., 2003). Although beneficial, laser photogrammetry and in-water size estimation training programs would also add complexity for participants, and training and maintenance of consistency may be problematic in an environment with a largely transient workforce. Overall I found that the size estimate data set from the dedicated surveys was robust enough to address my specific research question regarding basic population structure.

Lessons learned for using recreational divers to monitor sea turtles

Although the majority of the citizen scientists were professionals within the SCUBA diving industry, most lacked strong sea turtle species identification skills. Thus, although the logbooks were completed by dive professionals the majority of entries did not contain species identifications. A large proportion of the dedicated surveys were completed by dive centre D, which had an ongoing partnership with marine conservation volunteers. Through this program, volunteers received species identification training, which contributed to the 97% of dedicated surveys that were assigned species records. Thus, if species identification training, such as that from the dedicated surveys, was delivered to dive staff compiling logbook entries I would expect a higher rate of records to be accompanied by species level identifications. The dedicated survey data suggest that additional training is required to ensure correct identification between green and hawksbill turtles. I suspected this, as high rates of hawksbill sea turtles were reported in the dedicated surveys, which was inconsistent with species ratios observed by the authors or other researchers based locally (JL. Williams and SJ. Pierce unpubl. data). This likely suggests that participants were unable to easily distinguish between hawksbill and green turtles, particularly in juvenile stages. The challenge of requesting species identification from recreational SCUBA divers and non-scientific divers has been noted in the literature (Hickerson 2000; Houmeau 2007; Bell et al., 2008b). Even when other initiatives included data-confidence reporting criteria on survey forms, confidence in species identification was low (Bell et al., 2008b). Incorrect identification or encounters not assigned a species identification could be overcome in future projects using photographic records to accompany sightings reports (Hickerson 2000). Doing so would markedly increase the scientific utility of the study. Anecdotal information from study participants, and data from tracking studies elsewhere (Rees et al., 2013), suggest that individual turtles show fidelity to a particular site, and it cannot be known whether sightings were unique records of multiple individuals or repeat sightings of a single animal (Girondot 2010). The use of standardised photos of facial scales would allow for more detailed information about individual animals (Goodman-Hall and Braun-McNeill 2013) (similar to a mark-recapture study), and possibly allow analysis of residency and movement between dive sites (Schofield et al., 2008; Brooks et al., 2011; Marshall and Pierce 2012).

There is strong positive bias in the dedicated survey data because overall sample effort (e.g. total number of dive trips conducted) was not recorded. This data set was therefore not conducive to analysis of seasonal or longer-term trends. Underreporting of sampling effort is a problem frequently highlighted in citizen science programs (Roxburgh 2000; Barrett et al., 2002), and can, to some extent, be overcome by repeated requests for data collectors to report non- sightings (Bell et al., 2008b). Requests for operator dive effort for periods sampled by citizen scientists were unsuccessful, as has also been noted elsewhere (Lynch et al., 2004). Furthermore, effort and absence data are crucial in accounting for variable species detection rates that are typical of large opportunistic citizen science data sets (Fink et al., 2011; Van Strien et al., 2013). To address this problem in future citizen science projects, effort - in this case records of non-sightings - must be clearly documented over the course of the study. This could be overcome by establishing a regular or semi-regular reporting/recording process that is routinely monitored by scientific coordinators (chapter 3 focuses on the results of this data collection method). The greatest participation came from dive centre “D”, which filled in the dedicated surveys with ongoing collaboration from paying marine conservation volunteers, whose motivation, enthusiasm or incentive to participate may have influenced dive industry staff. It is likely that success with this operator could be attributed to their partnership with a volunteer ecotourism marine project. By hosting this volunteer project, they had a monetary incentive to sustain data collection.

It is apparent that the other data collectors, the dive staff from dive centres “A”, “B” and “C”, did not consistently report all encounters (presence or absence). Maintaining enthusiasm among voluntary sampling parties is an ongoing issue for this type of methodology (Uychiaoco et al., 2005; Bell et al., 2008a; Finn et al., 2010). Both emotional attachment and intimate encounters with the study animals have been postulated as influential to both participants' enjoyment levels and overall citizen-science programme success (Schänzel and McIntosh 2000; Cousins et al., 2009). These factors are important to consider when explaining the high variability in response rates in dedicated surveys. Given that turtle encounter rates throughout the sample period were relatively low (i.e. not guaranteed every dive trip), this may have affected participants' enthusiasm to report consistently.

Additionally, the high number of categories in the dedicated surveys (n = 17) may have prompted low consistency in reporting and high variability of response rates. Low reporting consistency is also hypothesised to be a result of the design of the dedicated surveys, as they relied on many participants to report sightings and thus individual accountability to report consistently was lost. I recommend simplifying the survey criteria to respond to specific research questions. Participation amongst dive operators participating in the dedicated surveys was not homogeneous, and it seems conceivable that data quality and quantity may be linked with motivation or incentive to participate (e.g. Campbell and Smith 2006). A suggested strategy to maintain enthusiasm and sustain volunteer-based projects is to demonstrate use and application of the collected data through information sessions and publications (Ryan et al., 2001). Overall, I found the use of logbook data was most useful for evaluating trends in the long term. With this in mind, consistent reporting rates and sustained participation are key factors and further investigation is merited. Long- term dive records compiled by individuals or single dive centres are likely to be a valuable source of information for assessing basic trends of sea turtles and other charismatic marine animals in many areas, if they can be trained to consistently report the data correctly and maintain intrinsic motivation.

Results of this study provide the first insights into foraging sea turtle populations in Mozambique based up citizen-science records. Citizen-science programs are highly dynamic; they require frequent training, data review and potential methodological changes during initial stages. My experience suggests that working with a single dive centre is likely to be logistically easier, in terms of training (as training cycles can be accommodated to staff turnover), and will yield more consistent and usable results if regular engagement with participants is possible. However, this data demonstrates that working with multiple dive centres can produce viable data and allows for maximising sample effort. Such a programme may also be most successful in locations where the survey animal is considered threatened or rare because this encourages reporting of encounters. Incorporating photographic records to validate both species and individual identification will also strengthen monitoring programmes (Holmberg et al., 2009). A particularly appealing feature is that similar programmes can be designed, implemented and maintained with few direct costs, and thus be widely adopted in developing nations and resource-restricted regions.

Chapter 2 Summary

- Enlisting the recreational SCUBA diving community to report sea turtle sightings is a potentially cost-effective solution for population monitoring in a region with limited resources.
- The effectiveness of recreational divers as monitors was tested through the review of 2 approaches: the use of a routine dive logbook with sightings, and data from a dedicated survey.

- These approaches provided 37 consecutive months of data between 2008 and 2011 from dive sites in Inhambane Province, Mozambique.
- A total of 317 sightings of loggerhead (*C. caretta)*, green (*C. mydas)*, hawksbill (*E. imbricata)* and unidentified turtle species were reported from 918 dives.
- While the dedicated survey collected more detailed behavioural data (e.g. response to divers and feeding behaviour), independent logbook records provided a more robust data set for analysis of sighting trends.
- Useful data on sea turtle species composition, size and distribution were obtained from both approaches, although there were concerns with regard to species identification and size estimates.
- With refined methodology, particularly the incorporation of photographic verification of species identification, reports from divers can provide cost-effective and useful data for monitoring.

Chapter 3

Use of Coastal Reefs by Green and Loggerhead Turtles in Southern Mozambique

This chapter builds on Chapter 2 by the improved reporting system for citizen scientists to contribute to a long-term dive log. In addition to the dive log, photo-ID and GPS track datasets were used to evaluate how sea turtles use coastal waters in the Praia do Tofo area, Inhambane Peninsula. The primary objective of this chapter was to understand coastal habitat use given the likelihood of high interactions/overlap with small scale fisheries. The secondary objective of this chapter was to assess the suitability of using photo-ID encounters to monitor sea turtles encountered by recreational divers. In this chapter, I also evaluate the suitability of using TORSOOI (TORtues marines du Sud-Ouest de l'Ocean Indien - Marine Turtles of the South West Indian Ocean) as a suitable tool for identifying loggerhead turtles.

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Abstract

Sea turtles spend the majority of their immature and adult lives in foraging grounds, yet few studies have examined their abundance and condition in these areas when compared to more accessible nesting beach habitats. Here, a five-year dive log, photo-identification (photo-ID) and surface encounter datasets were used to investigate the abundance, individual movements and distribution of sea turtles along 40 km of coastal reefs in southern Mozambique. A generalised linear model was constructed with turtle sightings as the response variable. Habitat type, year and day of the year, as well as underwater visibility, were significant predictors of turtle sightings. However, only 8% of the total variance was explained by the model, indicating that other variables have a significant influence on turtle movement and distribution. Photo-ID differentiated 22 individual green turtles (*Chelonia mydas)* and 42 loggerhead turtles (*Caretta caretta)* from 323 photo-ID encounters. A majority (64%) of the photos could be identified to individual turtles. Although residency times of up to 1152 days were calculated for juvenile green turtles, a low overall resighting rate indicates that individual turtles either had large home ranges or were transient to the area. Surface encounter data revealed a preference for nearshore shallow waters and an increased abundance close to reef systems. Sea turtles with preferences for shallow, nearshore habitats are likely to have an increased risk of encounters with opportunistic and targeted artisanal fishers who catch sea turtles.

Introduction

Understanding ontogenetic development of space use in marine megafauna species is a key aspect of marine megafauna movement ecology (Hays et al., 2016). A burgeoning question in this field is how megafaunal movements vary over space and time, essential knowledge for spatial planning and conservation management (Block et al., 2011; Hays et al., 2016). Sea turtles are one such megafauna species which move ontogenetically, spending part of their life in a juvenile nursery habitat and then migrating to an adult foraging habitat.

Juvenile sea turtles actively recruit to demersal neritic development habitats in tropical or temperate zones following several years of passive pelagic migration (Musick and Limpus 1997; Luschi et al., 2003), although evidence of juveniles recruiting to oceanic foraging areas has also been demonstrated (e.g. Hawkes et al., 2006; Dalleau et al., 2014). Cheloniidae (hard-shelled) species exhibit two strategies within their developmental habitat; 1) the area is shared with adults and will constitute the adult residential foraging grounds where juveniles will later spend their inter-reproductive period (Limpus and Limpus 2001; Bolten 2003) or 2) the area will be frequented only by juveniles that will subsequently shift to a different feeding area when they reach maturity (Musick and Limpus et al., 1997; Luschi et al., 2003). To date, the spatial and temporal variability of ontogenetic or developmental migrations in late stage juvenile sea turtles is the least known stage in the life cycle of sea turtles (Luschi et al., 2003; Godley et al., 2008; Hamann et al., 2010; Varo-Cruz et al., 2016).

Local variation in life history occurs both regionally and between different genetic stocks or regional management units (RMU) for each sea turtle species. A synthesis on satellite tracking revealed greater behavioural and ecological plasticity in cheloniidae than previously thought (Godley et al., 2008; Casale et al., 2012). Migration routes of post-breeding adults revealed four general migration strategies :1) oceanic and coastal movements to fixed neritic grounds; 2) coastal shuttling between fixed or seasonal neritic sites; 3) local residence; and 4) pelagic foraging (Godley et al., 2008). For the south west Indian Ocean (SWIO) loggerhead populations, oceanic and neritic foraging behaviours have been shown in late stage juveniles (Dalleau et al., 2014). Migrations of these late stage juveniles can be broadly categorised into three groups; northern migration towards neritic waters of Kenya, Somalia, Yemen and Oman (which hosts the largest nesting rookery in the region), a southern migration towards the smaller South African rookery yet remaining in productive pelagic waters, and a third group where behaviour could not be clearly defined but animals remained offshore from Reunion Island, or the eastern coast of Madagascar (Dalleau et al., 2014). The pelagic migration of late stage juvenile loggerheads travelling south is distinct and different from neritic shuttling migrations (between nesting and foraging areas) as revealed in satellite tagged post-nesting turtles from South Africa (Schroeder et al., 2003; Luschi et al., 2006; Dalleau et al., 2014). Throughout their global ranges, adult loggerhead turtles display strong site fidelity to residential areas and establish feeding home ranges at these sites (Hughes 1974; Limpus and Limpus 2001; Godley et al., 2003). Within the SWIO, post-nesting loggerhead females migrate north, actively hugging the coast from the Maputaland rookery into Mozambican coastal waters (southern and central provinces) (Luschi et al., 2006). The end point of these migrations is thought to be individually-specific neritic feeding areas which are discrete foraging grounds for adult loggerheads (Luschi et al., 2006).

Contrasting this, green turtles within the SWIO adopt an alternative strategy, whereby mixed age/size aggregations at foraging grounds are common (although niche partitioning between size/aged animals occurs within a foraging area (Ballorain et al., 2010)). Foraging habitats across the SWIO are shared by different breeding populations (stocks) of the SWIO and beyond

(Dallaeu 2013; Hays et al., 2014; Bourjea et al., 2015). Typically, post-nesting green turtles migrate to neritic resident foraging areas (Broderick et al., 2007; Garnier et al., 2012), such as those tracked migrating from Vamizi Island in northern Mozambique using primarily neritic (but also some evidence of pelagic) migratory routes to foraging grounds in Kenya, Tanzania and north-west Madagascar (Garnier et al., 2012). Genetic analysis (mtDNA) at these foraging sites have allowed an evaluation of the stock and the natal origin of animals (Bowen and Karl 2007) can be inferred, which ultimately provides insight into ontogenetic migration (displacement distances) (Hays and Scott 2013). However, along the east African and Malagasy coast, significant data gaps exist regarding the genetic composition of animals within mixed foraging grounds resulting in uncertainty about natal origins and ontogenetic migrations undertaken to reach the foraging area (Bourjea et al., 2015).

Immature turtles, having survived the higher mortality rates associated with hatchling and post-hatchling life stages, generally have the highest stage-specific demographic sensitivity within a population (Heppell et al., 2003). Thus, anthropogenic threats that disproportionately impact immature turtles or are prevalent in developmental habitats are likely to result in overall population decline (Heppell et al., 2003; Gerber and Heppell 2004; Wallace et al., 2008). Yet for many of the world's sea turtle populations empirical data on the distribution and condition of important foraging areas, or the behaviour and ecology of foraging turtles is lacking (Hamann et al., 2010). Describing sea turtle foraging areas with details of which animals (species, individuals and age classes) occupy an area, their use of the area (purpose of occupancy, residency patterns, habitat preferences, area/space occupied) and temporal patterns of their use (daily, seasonally and annually), is critical for effective conservation planning and targeted management (Luschi et al., 2006; Hamann et al., 2010; Casale et al., 2012). Contributing to these fundamental gaps in sea turtle foraging ecology, the environmental and behavioural mechanisms (or combination of) which influence/trigger the timing of ontogenetic migration and the destinations are poorly understood. In adult foraging areas it has been proposed that the selection of these sites is influenced by the drift pattern undertaken as hatchlings (Hays et al., 2010; Scott et al., 2014). As such, the prevailing oceanography around nesting rookeries may be crucial to the selection of foraging areas used by adults (Luschi et al., 2003; Hays et al., 2010). Regional evidence of this theory exists from a green turtle rookery at Vamizi Island, northern Mozambique where prevailing oceanography influences the diversity of residential foraging grounds used by adults (Garnier et al., 2012). Given the seasonal characteristics (seasonal monsoon systems) and complexity of oceanic circulation (cyclonic and anti-cyclonic eddies and lack of an ocean-scale annual gyre) in the Indian Ocean, it is possible that a greater variability of ontogenetic migration patterns occurs than in sea turtle populations in other ocean basins (Dalleau et al., 2014). This suggests that predicting and identifying migratory corridors and the final destination (foraging grounds) of ontogenetic migrations (for spatial planning or threat assessment) is likely to be more challenging for sea turtle species in the SWIO.

The east African coast is presumed to host extensive foraging areas (Bourjea et al., 2015), and the coastal waters of southern Mozambique are no exception. Five sea turtle species inhabit southern Mozambique, yet their spatial distribution, habitat use and population structure has not been studied (Louro et al., 2006). Coastal foraging areas generally contain a mixture of age/size classes (and species), but a size structure bias can occur

(Hatase et al., 2002; Ballorain et al., 2010). Most knowledge on sea turtle population ecology in Mozambique relates to loggerhead turtles (*Caretta caretta*) which are represented by a single genetic stock: the SWIO genetic stock (Hamann et al., 2013; Fernandes 2015). The species nests along much of the country's southern coastline, and their most studied rookery within the South West Indian Ocean (SWIO) occurs across the boundaries of Mozambique and South Africa (Nel et al., 2013). Beyond the southern Mozambican nesting grounds, loggerheads also spend extended periods of time in what are thought to be coastal foraging grounds in the Inhambane Province, southern Mozambique (Hughes 1974; Papi et al., 1997; Luschi et al., 2006; Pereira et al., 2014c). Their foraging and migration areas are not well known, although tagged juveniles have demonstrated neritic and oceanic foraging behaviours (Dalleau et al., 2014). Based on population trends from the South African coast, the SWIO loggerhead population, is listed as 'Near Threatened' on the IUCN Red List (Nel and Casale 2015), with the population thought to be stable and showing signs of increase (Nel et al., 2013).

Information on green turtles (*C. mydas*) in Mozambique has been derived from nesting census work on Vamizi Island in the country's north, thought to be the most significant nesting rookery in Mozambique (Garnier et al., 2012; Louro and Fernandes 2013). Within the Inhambane region, mixed-size green turtles (40–110 cm curved carapace length) utilise nearshore reefs (Williams et al., 2015), yet it remains unclear whether these reefs represent foraging habitat (and/or migratory corridors) for the species. Green turtles occur extensively throughout the Mozambique Channel (Bourjea et al., 2007). Unlike loggerhead turtles, foraging and nesting green turtles in the WIO are comprised of several genetic stocks (Bourjea et al., 2015). Turtles from two of these stocks exist in Mozambican waters: the Northern (NMC) and Southern

Mozambican Channel (SMC) stocks (Bourjea et al., 2015). The NMC stock consists of multiple breeding populations (e.g. Seychelles, Northern Madagascar, Kenya, Mayotte, Tromelin), however the SMC Stock is thought to primarily consist of turtles from the Europa rookery (Bourjea et al., 2007). Anthropogenic exploitation of sea turtles from their mixed-stock foraging grounds can reduce breeding populations across a region (Bowen and Karl 2007). Theoretical modelled scenarios of anthropogenic perturbations affecting foraging grounds of the SMC show increased pressures to the NMC stock, and could cause regional implications. However, limited empirical data exists to validate this prediction (Dallaeu 2013). It is clear that detailed investigations into foraging areas within the region, particularly along the east African mainland coast, is required.

The absence of regional knowledge on the ecology of foraging sea turtles in the region makes it difficult to assess and quantify the impact from various threats, such as incidental and direct take from small scale fisheries (SSF). SSF often comprise the majority of the fisheries sector in developing countries (Béné 2006, Alfaro-Shigueto et al., 2010). SSF are widespread globally throughout nearshore habitats and easily-accessible coastal waters (Francis et al., 2001) and high bycatch rates of sea turtles, cetaceans and elasmobranchs occur (Koch et al., 2006, Soykan et al., 2008, Mancini et al., 2011a). Coastal net fisheries may be the largest single threat to sea turtle populations globally (Gilman et al., 2009) and within Mozambique, artisanal gill net and beach seine fishing are thought to have the greatest impact on sea turtles, marine mammals and elasmobranchs (Kiszka 2012). In Mozambique, SSF contribute to 91% of the total marine fisheries catch (IFAD 2011), and the 2006 national census for artisanal marine fisheries found that over 280 000 people depend directly on artisanal fishing, with another 90 000 dependent on obtaining resources from diving or shore line collection (Menezes and Smardon 2011). The abundance of turtles caught by artisanal fisheries throughout the Mozambique Channel is thought to overshadow commercial fisheries catches (Rakotonirina and Cooke 1994; Humber et al., 2011; Nel et al., 2013; Bourjea et al., 2015). Specifically, in Mozambique the number of people and boats engaged in SSF is increasing, even though productivity is declining (IFAD 2011). Gill netting and other artisanal fisheries (spearfishing, beach seining, purse seining) occur extensively throughout Inhambane Province, where my study was undertaken.

Advances in the understanding of foraging turtle ecology and ontogenetic migrations are likely to require a diverse approach using information from tracking, tagging, genetic stock and remotely sensed environmental data collected collaboratively across the region (Dalleau 2013; Bourjea et al., 2015). An additional technique which could yield valuable information from foraging grounds is photographic identification of individuals. The low cost, low-tech and non-invasive nature of Photo-ID in contrast to other techniques (Fastloc, Argos or acoustic tagging), has propelled its adoption, as a tool for in-water monitoring of animals (Schofield et al., 2008; Jean et al., 2010; Dunbar et al., 2014; Carpentier et al., 2016), particularly in developing countries where application of alternative technologies may be hindered by resource limitations. Photo-ID can potentially provide insights into the use of neritic coastal areas by sea turtles as foraging grounds or migratory corridors, and may further enhance understanding of late stage juveniles and ontogenetic space use. This chapter uses three complementary datasets (dive logs, photo-ID and a surface encounter dataset) to investigate the size structure, residency, environmental, spatial and temporal trends of sea turtles in coastal habitats around the Inhambane peninsula in southern Mozambique. I attempt to clarify the spatial use of this area by green and loggerhead turtles. I consider these findings within the context of known SSF risk to sea turtles in this region, along with the practicalities of applying photo-ID from citizen science.

Methods

Study Area

The study was conducted in the coastal waters adjacent to the small village of Praia do Tofo on the Inhambane peninsula of Inhambane Province, southern Mozambique (-23.51 °S, 35.23 °E) (Fig. 3.1). A detailed study site description was provided by Williams et al. (2015) (Chapter 2). Fifteen different reef areas all routinely visited by SCUBA dive tour operators, were selected for inclusion in this study. These reefs were located from 500 m to 15 km offshore along a 40 km stretch of coast. All are primarily rocky, with low hard coral diversity and range in mean depth from 11 to 33 m. Using prominent coral taxa the sites could be distinguished into four habitat types: 1) plate corals; 2) soft corals; 3) rocky reefs with branching tree corals (Dendrophilliae); and 4) mixed (coral and macroalage). These four habitat types were separated into distinct spatial groupings, with plate coral habitats found in the northern offshore reefs, rocky reefs with branching corals found in deeper waters directly offshore from Tofo Bay, and soft coral reefs found in deeper waters in the south. All other sites were classified as mixed macroalgae and coral habitat type, and were found in nearshore shallow areas (Fig. 3.1). Ocean conditions were dynamic and swell sizes (0.1 m – 3 m) and underwater horizontal visibility (5 – 30 m) varied day to day. Horizontal visibility was estimated and reported by experienced divers.

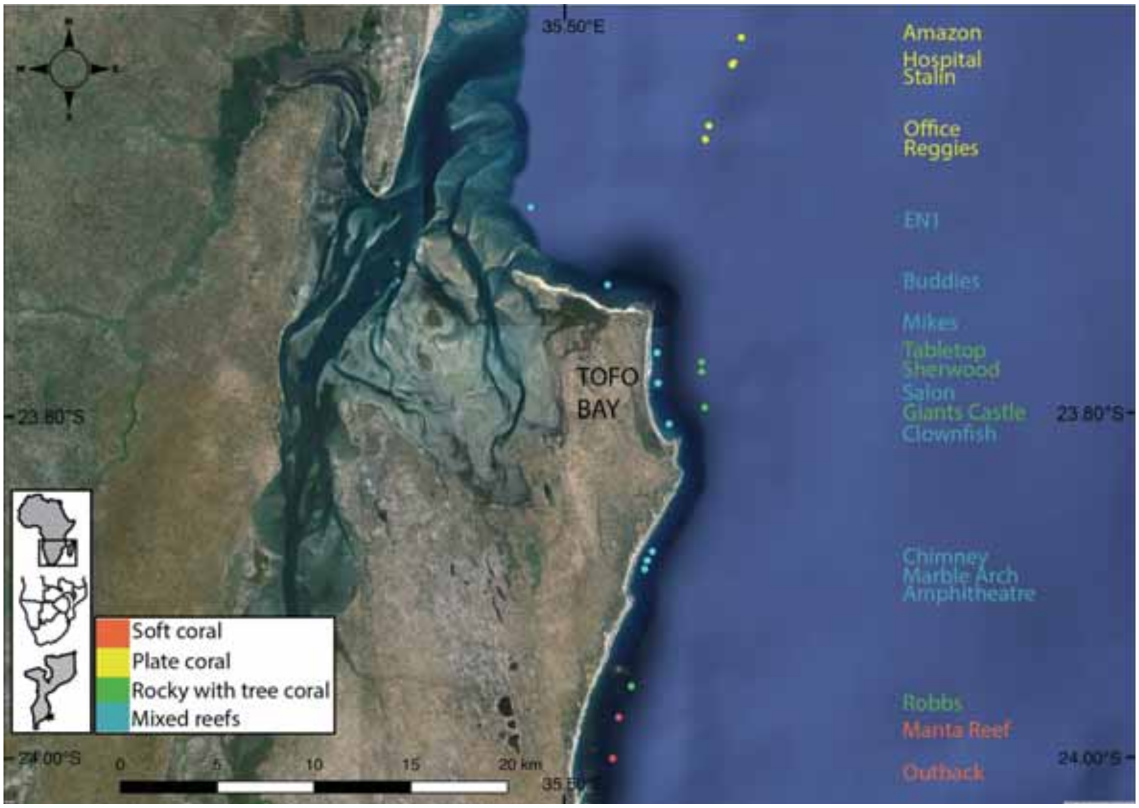

Fig. 3.1. Study area of Praia do Tofo and the dives sites (location marked with dot, names offset) and habitat types of Inhambane Peninsula.

In-water data collection and analysis

Citizen scientists and researchers contributed toward both dive logs and turtle photo-ID collection in Praia do Tofo. Data from 1, 403 dives undertaken between Aug 2011– Sept 2015, (a total of 1, 055 diving hours) were available for analysis. To avoid possible data duplication within a day, or between dive groups, only one record per species per day at each specific dive site was used, except where photo-ID records were available to confirm that multiple individuals were present. Dive logs were completed by long term and highly experienced divers (research assistants or project leaders of local marine conservation organisation or dive instructors). Divers were trained in species identification (sea turtles, elasmobranches and cetacean), size and carapace estimation techniques (Williams et al.,2015/

Chapter 2). Diver training included estimating distances underwater (e.g. visibility) by using the known size of the dive boat as a size guide. Most carapace length data were collected by trained marine research assistants using a laser photogrammetric system set up for sizing megafauna species underwater (whale sharks, manta rays and turtles) (Rohner et al., 2011). While too few photogrammetric measurements were obtained for inclusion in this study, the equipment enabled two laser dots, set at 50 cm apart, to be projected onto the animal or nearby surface (i.e. benthos, cave wall), which the diver then used as a scale bar to estimate turtle size in the field. A number of these divers also assisted with sea turtle mortality studies, where they were trained to measure and report curved carapace length and curved carapace width of carapaces discarded from illegal take/use (on land).

Additional detailed turtle sightings sheets (for the same study period) were completed for each record (described in Williams et al., 2015/ Chapter 2). The turtle sightings sheets facilitated the collection of more detailed turtle behaviour information and were designed to be submitted in coordination with the dive log. However, duplicate records from different reporters, and positive bias issues occurred because each record was clearly identified to a particular dive log entry. Turtle sightings sheets were not used to evaluate sightings trends, however they did provide an additional subset of estimated curved carapace length (CL) (n total = 679) from the same study period, and were available for green, hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), and loggerhead turtles, and for additional encounters not identified to species level. Where possible dive log records were validated for species identification using photo-ID records submitted.

The mean turtle sighting rate per minute of diving was calculated from the dive log dataset. A Kruskal-Wallis chi-squared test was used to compare sightings rates among sites. Additional pairwise comparisons were made using Wilcoxon rank sum test to compare sightings rates among the four habitats.

Dive log analysis

Dive log data were used to construct a negative binomial generalized linear model (GLM) with natural splines using R (R Core Development Team 2016), with turtle abundance set as the response variable. Due to limitations with sample sizes of loggerhead, green and unidentified turtles, species were pooled for this analysis, while records of hawksbills (n =11) and leatherbacks (n =2) were removed from dataset. Fifteen variables were investigated as possible predictors of turtle abundance (Table 3.1). To improve the model's predictive ability, the data range of some predictors were capped with minimum and maximum values (distance from shore ≥ 8km; visibility ≥5m, ≤25m; max depth ≤29m; average depth ≤22m; and bottom surface temperature (BST) ≥18^{o}C ≤27 ^{o}C). The best-fitting model was conservatively assessed using a stepwise Akaike's Information Criterion (AIC) function with the default penalty per parameter set at k = 2, and a dropterm chi-squared function performed on the AIC-supported model. The significance of each predictor and their suitability for inclusion in the final model was selected using a chi-squared test (Venables and Ripley 2002). In the model output figures, the y-axis is a relative scale, so that a y-value of zero is the mean effect of the adjusted predictor on the response; a positive y- value indicates a positive effect on the response; and a negative y-value indicates a negative effect on the response. If a horizontal line can be placed between the 95% confidence limits (dotted lines), this implies that the relationship between the response and the predictor is not significant. These lines tend to diverge near the extremes of the range for continuous predictors as a consequence of fewer observations. Kruskal-Wallis chi-squared and Wilcoxon rank sum test tests were used to perform multiple comparisons among levels of categorical predictors.

Table 3.1. Potential predictors of sea turtle abundance considered for analysis.

Predictor	Data type
Year	Numerical (2011- 2015)
Day of the year	Numerical (1 – 365)
Dive duration (min)	Numerical (10.0 – 124.0)
Time of day	Categorical (AM or PM)
Dive site	Categorical
Distance from dive site to shore (km)	Numerical (0.5 – 8. 0)
Average dive depth (m)	Numerical (5.0 – 22.0)
Maximum dive depth (m)	Numerical (25.0 – 29.0)
Underwater visibility (horizontal) (m) (Optimal visibility > 9 m)	Numerical (5.0 – 25.0)
Bottom surface temperature (degrees ^{o}C)	Numerical (18.0 – 27.0)
Current strength	Categorical (0, 1, 2, 3)
Surge strength	Categorical (1, 2, 3)
Other marine megafauna present*	Binomial (1 = present or 0 = not)
Habitat type	Categorical (plate corals, soft corals, rocky reefs with branching tree corals, mixed (coral and macroalage))

Shelter availability	Binomial (1 = Site with cave or ledge, 0 = not)

* Other species included; reef manta ray (*Manta alfredi*), giant manta ray (*Manta birostris*), small-eyed stingray (*Dasyatis microps*), leopard shark (*Stegostoma fasciatum)*, whale shark (*Rhincodon typus*), bow-mouth guitar shark (*Rhina ancylostoma)*, black-tip reef shark (*Carcharhinus melanopterus)*, white-tip reef shark (*Triaenodon obesus*), bottlenose dolphin (*Tursiops truncatus)* and humpback whale (*Megaptera novaeangliae)*.

Photo-identification analysis

Detailed dive logs were coupled with photo submissions (April 2010-September 2015) of each turtle encounter if available, allowing confirmation of species. I used photo-ID to detect individual site preferences, residency patterns and movements. Photo-ID is based on the premise that each individual turtle can be reliably distinguished and recognised in subsequent encounters (Schofield et al., 2008; Jean et al., 2010; Dunbar et al., 2014). I adopted the TORSOOI system (TORtues marines du Sud-Ouest de l'Ocean Indien - Marine Turtles of the South West Indian Ocean: www.torsooi.com) to identify individual turtles by their facial scute patterns. This database system uses recognition software (described in detail by Jean et al., 2010) to compare and sort the photographs, presenting the top matched images in descending order of similarity. If the photograph showed clearly visible facial scutes, and the angle of the camera was within 20^{o} of the side of the turtle's head, an encounter number was assigned to each record, and each encounter identified as a specific individual. Left and right facial profiles of each animal were visually inspected and classified using a three-digit code to describe each scute on the turtle's head, posterior from the eye to the neck, and from the line of the upper jaw to the top of the turtle's head, following Jean et al., (2010) (this process required < 2 min per profile). To my knowledge, the recognition software used in TORSOOI has only been tested within green and hawksbill turtles (Jean et al., 2010; Carpentier et al., 2016). Suitability for loggerheads, was tested by comparing manual visual identification against TORSOOI matching. Each encounter was visually coded and assigned individual identifications for the entire loggerhead dataset (approx. 10 min each). After this, I repeated the process using the semi-automatic profile coding tool built into TORSOOI. Results between manual matching and TORSOOI were not significantly different, hence I report results based from the TORSOOI (Refer to Fig. S2.1 for an example of Photo-ID resighting records from one individual showing left and right profiles and Fig S2.2 for examples of photo quality and variation in submissions. Combinations of high angle or low clarity (not both) could be used to determine individual scute patterning with the TORSOOI semi-automated system in appendix 2).

Sightings data for individual green and loggerhead turtles were used to assess the lagged identification rate (R_{Li}), the probability of re-identifying known individual turtles over increasing time periods, here measured in days (Whitehead 2001). While encounters of hawksbill turtles were reported, the photo-ID dataset was insufficient (n < 10) for population modelling. Using the movement module in SOCPROG 2.6 software (Whitehead 2009), empirical data were compared to eight model scenarios representing both closed and open populations with various combinations of emigration, re-immigration and mortality (including permanent emigration) (see Table 3.4 for model descriptions). Data were bootstrapped 100 times to generate standard errors for R_{Li} and parameter estimates for the fitted models. Either the AIC (loggerhead turtles) or quasi-AIC (QAIC; green turtles) were used to select the best-fitting model/s for each species, with QAIC used due to over-dispersion of data (Whitehead 2007).

Surface encounters

GPS tracks of survey effort covered by dive boats (n = 2) of one dive operator were available from February 2012 to September 2015 for a subset of the total dive trips, with additional commercial snorkelling trip (ocean safari) records added to the dataset (n = 656 total tracks with a combined length of 28, 232 km and n = 138 turtle surface encounters). An active visual search for megafauna occurs on these trips to maximise the snorkel encounter opportunities with charismatic megafauna species. A comprehensive description on search pattern and vessel characteristics used for diving and ocean safaris can be found in Pierce et al., (2010). The dive operator frequently combined a double dive trip with an ocean safari which meant that animals were spotted on transit to dives and actively searched for in transects between dives. As noted in Pierce et al., (2010) searches were aided on the majority of trips by the use of a removable spotting chair, which raised a single observer to approximately 3m above sea level to broaden the search corridor. The GPS track dataset was biased towards early morning (dive effort bias) and midday (ocean safari trips) rather than afternoon. However, the biased dataset included search effort from all working hours (6am – 5pm). The study area was gridded into 500 x 500 m cells, and the total length of boat tracks within each cell were converted into area measurements by multiplying by the estimated effective search area, 30 m (I estimated this by proposing that 15 m on either side of the boat could be considered an appropriate yet conservative spotting distance to spot animals at the surface, which was successfully applied in field settings). Surface encounters were only reported when an animal was spotted, from the boat, on the surface. Turtle surface encounters were converted to daily presence / absence within each 500 m x 500 m cell, and multiplied by daily search effort (area) to calculate sightings per unit effort (SPUE). Given that SPUE is not standardised for search time, or variability in boat speeds (dive boats used were not fitted with speedometer), this may lead to an overestimation of these sightings (Braun-McNeill and Epperly 2002). As the search area and effort was consistent across years (Fig. 3.2), SPUE is presented for the entire study period. All spatial analyses were conducted using Quantum GIS (v 2.14 Essen) (Quantum GIS Development Team, 2016).

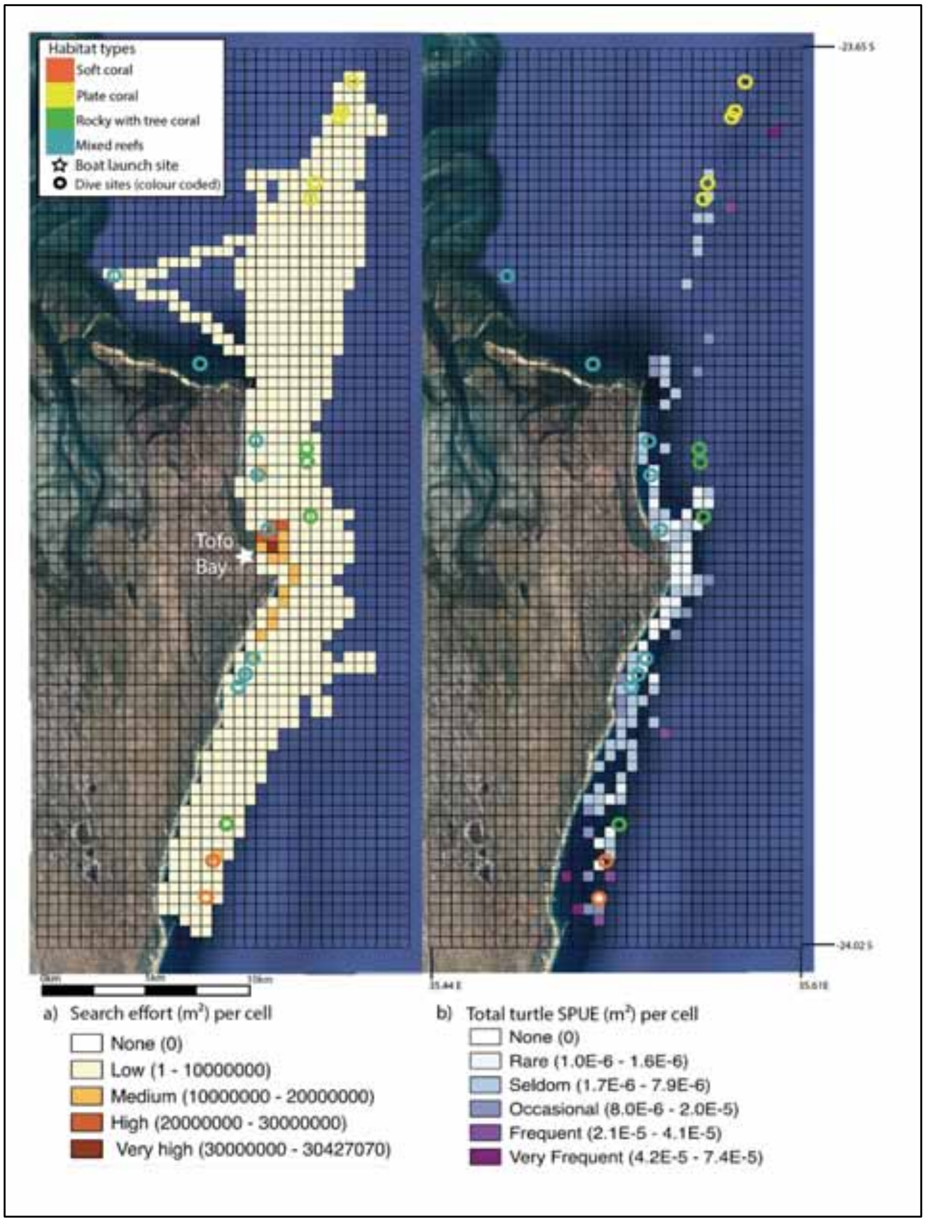

Fig. 3.2. Search effort (insert a) (standardized in m^2 and gridded into 500 x 500 m cells) from boat trips along the Inhambane coast, Mozambique. Area covered was estimated at 15 m on either side of the boat. Search effort, as estimated through total track length for each year, was similar: 2012 = 7336.05 km, 2013 = 8910.39 km, 2014 = 6391.73 km and 2015 = 5593.36 km. Turtle surface encounters (insert b) per unit effort (SPUE) m^2 of search effort conducted per 500 x 500 m grid cell, 2012-2015. Dive sites are overlaid onto both inserts (represented by open circles) and colour coded according to

four basic habitat types. Location of the boat launch site is marked on insert a.

Results

Dive Log analysis

Dive effort was greatest in 2014 (n = 464) (cf. 2011 (n = 71), 2012 (n = 256), 2013 (n = 321) and 2015 (n = 282)). The mean monthly number of dive trips was 28 over the entire study duration with a variation in effort dependent on year (2011 = 14, 2012 = 22, 2013 = 27, 2014 = 39, 2015 = 31). Minimum monthly dive effort was 10 dives and maximum monthly effort was 48 dives. Diving occurred all year and dive effort was not strongly influenced by seasons (or seasonal weather) (Dec-Feb mean = 70, Mar-May mean = 75, Jul- Aug mean = 74, Sep- Nov mean = 62). Data for the full 12 months was not available for analysis in 2011 (only commencing in August) or 2015 (data up to Sept) and this is likely to influence the effort/trends. Dive effort was biased towards the morning (n = 1015) rather than afternoon (n = 388) although afternoon dives were strongly biased towards shallow mixed habitat reefs. Mean depth of dives was 18.0 ± 0.1 m and mean horizontal underwater visibility was 13.4 ± 0.1 m. On 18% of dives visibility was suboptimal (i.e. $\geq$5 m $\leq$ 9m (n = 254). Dive effort varied minimally (difference of 153 dives) between habitat type with ‘soft coral’ reefs the most frequently dived habitat (n = 423, 2 sites), ‘rocky sites with tree coral’ (n = 377, 4 sites), ‘mixed’ (n = 333, 8 sites) and least frequently dived were ‘plate coral’ habitats (n = 270, 5 sites).

In total, 399 turtles were reported across 1403 dives, over a period of 4 years and 2 months. Turtle sightings (mean sightings per minute of diving) were highly variable at each site and among dive sites (Fig. 3.3) (Kruskal-Wallis chi-square = 30.1857, d.f. = 3, p <0.001). Patterns among habitat types and turtle sightings were less distinct. Although the ‘soft coral’ habitat sites had the highest densities of turtles, differences among the four habitat types were not significant. However, given that dive effort and turtle sightings were not consistent among sites (n = 17 to 311, Fig. 3.3) I proceeded with inter-habitat pairwise comparisons using a Wilcoxon rank sum test. This identified significant differences in turtle density between the “mixed + soft” ($p = 0.00059$), “plate + soft” ($p = 0.00621$), and “soft + tree” ($p = 1e\text{-}05$) dive site groups where soft habitats had highest turtle sighting rates.

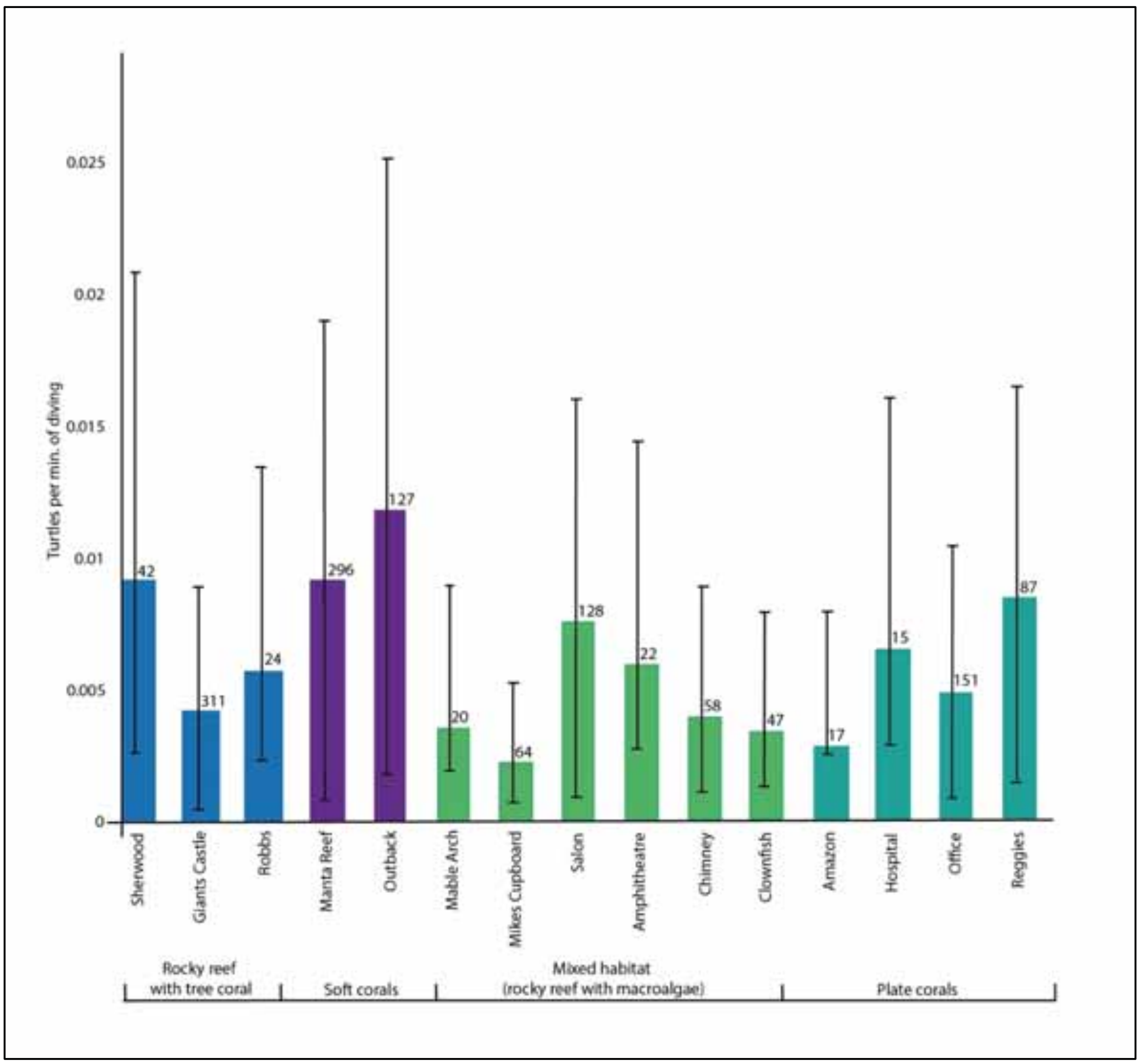

Fig. 3.3. Mean turtle sightings per minute of diving for each dive site, sorted by habitat groupings, with standard error bars and dive effort.

Most (88.5%) turtle encounters reported by divers were identified to species level. The sizes of turtles reported, variation in which could be indicative of reproductive immigration or emigration, did not correlate with day of the year. Varying size classes were reported throughout the year for all species. Mean carapace lengths for green and hawksbill turtles were similar at 0.7 m (green 0. 6 ± 0.2 m CL and hawksbill 0.6 ± 0.2 m CL). Loggerheads were commonly reported at carapace lengths of 1 m (mean CL 0.8 ± 0.2). The range of size classes reported was greatest for green turtles (0.3 – 1.4 m, Fig. 3.4).

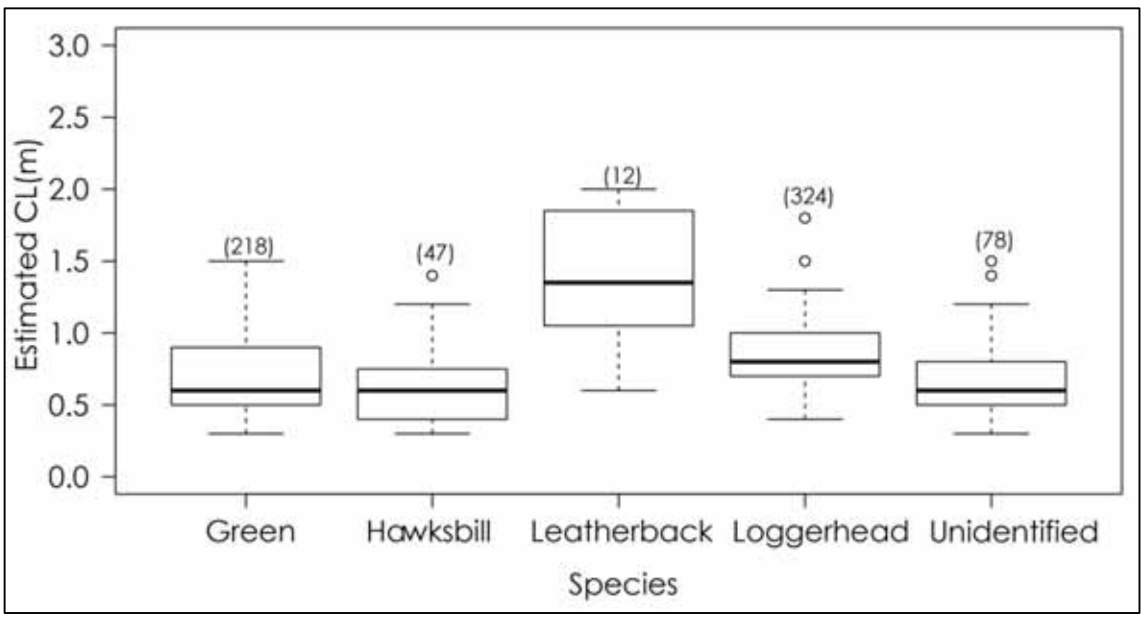

Fig.3.4. Estimated carapace length (CL), with species-specific n value in brackets. Linear descriptive statistics show range and spread CL data between the 25th and 75th percentiles, with the bold line representing the median and outliers plotted as circles.

The final GLM for turtle abundance had limited predictive power, explaining only 8% of the total variance in turtle sightings. Five predictors were retained for the final model: year, day of the year, time of day, visibility and habitat type (Table 3.2). Year was a significant predictor of turtle sightings in the final GLM. Turtle abundance did not vary significantly through 2011 to 2015 (Kruskal-Wallis chi-squared = 4.8214, df = 4, p = 0.3061). A small inter-annual variation was present, with turtle abundance lowest in 2011(Fig. 3.5a). Sightings fluctuated through the year, with a peak occurring around day 250 (early September) and remaining high for the remainder of the calendar year even though seasonal dive effort was slightly higher during the autumn season (March to May) (Fig. 3.5b). There was no obvious relationship between time of year and the size distribution of turtles present, eliminating breeding-related migrations as a likely contributor to this result (as above). Turtle sightings were highest in the soft coral habitat, which also received the heaviest diving effort (Fig. 3.5c). Time of day was a significant predictor of turtle abundance: afternoon dives (primarily shallow dives < 15 m) reported higher number of animals than morning dives, even though dive effort was > 2.5 times greater in the morning (Fig. 3.5d). Underwater visibility was highly dynamic within each season and across years. Higher underwater visibility yielded higher turtle abundance (Fig. 3.5e) and visibility was optimal on 82% of dives (n = 1403).

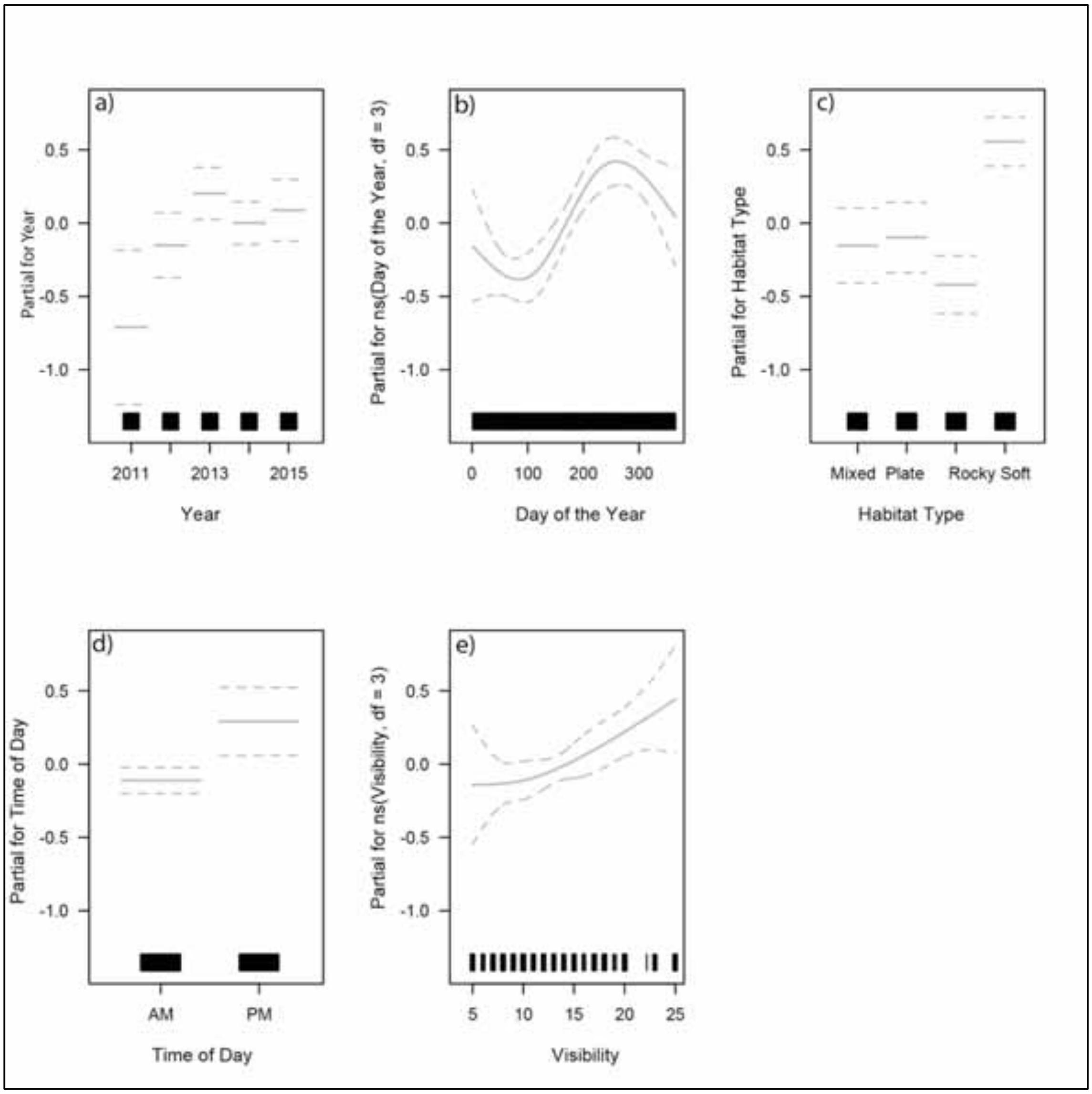

Fig. 3.5. Generalised Linear Model outputs showing the relationship between sea turtle sightings (abundance) and all significant predictors. The rug plot along the x axis indicates sampling effort, and dotted lines indicate 95% confidence intervals (partial plots for; a) year, b) day of the year, c) habitat type, d) time of day and e) visibility).

Table 3.2. Percentage variance explained by each predictor in the GLM and the significance values of a chi-squared test (χ^2) performed on the AIC-supported models..

Predictors	Variance	χ^2	p
Year	0.39	4.48	0.34
Day of the year	2.44	27.93	3.76E-06
Habitat type	3.83	43.03	2.43E-09
Time of day (AM/PM)	0.45	4.95	0.03
Visibility	0.88	9.46	0.01

Photo-ID

A total of 1,137 images (n = 323 encounters) were submitted to the photo-ID project I established. Submissions were made by local researchers or citizen scientists between March 2010 and September 2015. The number of photos submitted varied per encounter, as did the subject area of each photograph (left or right facial scutes, carapace or some combination thereof). Citizen scientists also provided a small number of pictures (n = 8) taken between 2005 - 2010, before the project commenced. From these combined data I identified 22 individual green turtles and 42 loggerhead turtles (Fig. 3.6). Most turtles were only seen once, and green turtles were more frequently re-sighted than loggerhead turtles (Fig. 3.6).

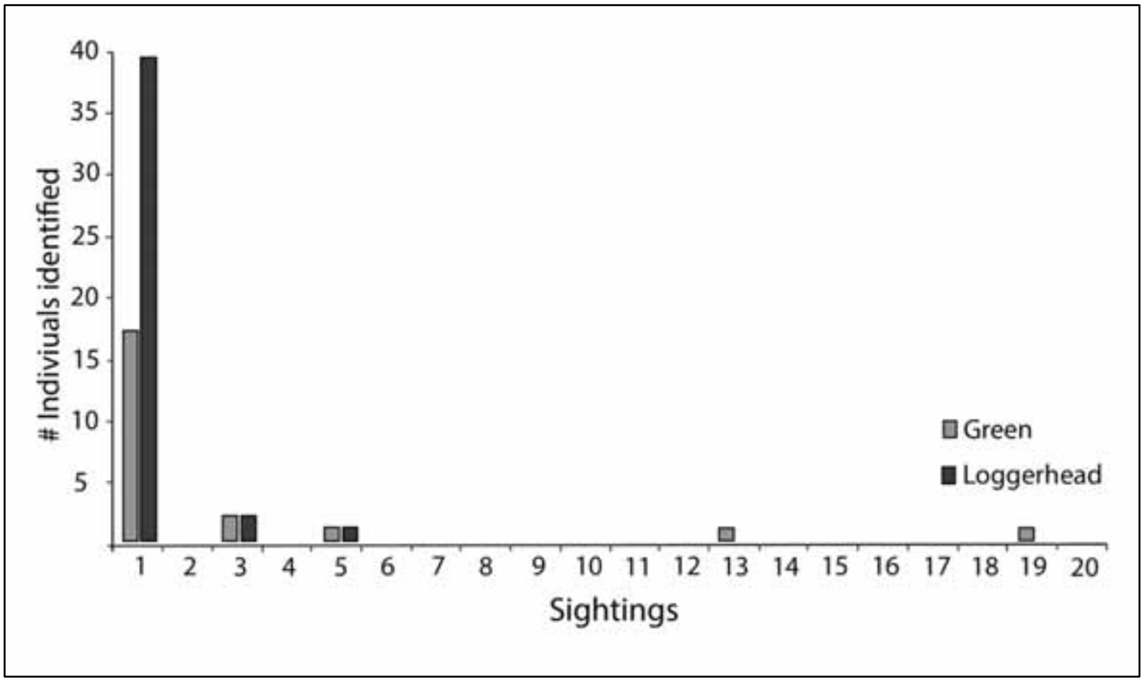

Fig. 3.6. Number of sightings occasions of each individually identified green *(C. mydas)* and loggerhead turtle *(C. caretta),* captured through photo-identification.

Overall turtle encounter rate during the study period was low, with turtles sighted on only 24.1% of dives, at a sighting rate of 0.4 turtles per hour. Loggerheads were the most frequently sighted species at 0.2 turtles per hour (n = 210), but they had the lowest percentage of usable photos (i.e., identifiable to individual) submitted (51.7%). The majority of turtle encounters were identified to species (green n = 157, hawksbill n = 12, leatherback n = 2, unidentified species n = 23). Of 399 sea turtles observed, 80% had photo-ID encounters submitted (n = 323), of which 64% (n = 204) had scute patterns that could be coded out to determine individual identity. Although only a few hawksbill turtles were sighted (n = 12) these animals were easily photographed and 86.4% (n = 10) could be identified to a specific individual. Green turtle encounter salso had a higher percentage of encounters where individual scute profiles could be distinguished (n = 125/157, 77.6%).

Loggerhead turtle site residency and lagged identification rate

Forty-two individual loggerhead turtles were identified from photographic encounters submitted between 2010-2015 (plus three additional encounters from 2007-2008). Only three of these individuals were re-sighted three (n =2) and five (n = 1) times over the study (Fig. 3.6). The longest time between sightings of a loggerhead turtle was 532 days for an adult individual. Of the eight models (Table 3.3), AIC results determined that models C and D (ΔAIC < 2) were the best fit, indicating that the population was best represented by an open population with some emigration and mortality (Table 3.3). There was no support for closed population models. The small sample size of this dataset means model outputs should be regarded as indicative rather than quantitative. Estimates of population size were low, and consistent between models C and D, with LIR decreasing to slightly above zero over time.

Table 3.3. Variation in AIC scores for the eight models fitted against the loggerhead turtle data. For best fitting models, population parameter estimates generated from Models C and D fitted against lagged identification rate for loggerhead turtles, presented with standard error and lower and upper 95% confidence intervals. Whereas models A and B represent closed populations, models C to H represent open populations with varying parameters. Descriptions of the models fitted against lagged identification rate of loggerhead turtles (*C. caretta*) are included below.

Model	Loggerhead ΔAIC	Parameter	Value	SE	Lower 95% CI	Upper 95% CI
A	19.455					
B	19.455					
C	0.000	a1= emigration rate	0.004	0.334	0.003	0.962
		N= 1/a2	0.086	0.063	-0.072	0.138
D	0.000	a1 = N	11.636	8.486	7.227	38.937
		a2 = Mean residence	246.079	81.558	0.000	342.427
E	22.503					
F	23.455					
G	0.224					
H	140.405					

Model	Description/ Scenario
A	Closed ($a1^{-1}$ = N)
B	Closed (a1 = N)
C	Emigration and mortality (a1 = emigration rate; $a2^{-1}$= N)
D	Emigration and mortality (a1 = N; a2 = mean residence time)
E	Emigration + re-immigration (a1 = emigration rate; a2 $(a2 + a3)^{-1}$ = proportion of population in study area at any time)
F	Emigration + re-immigration (a1 = N; a2 = mean time in study area; a3 = mean time out of study area)
G	Emigration + re-immigration + mortality

H	Emigration + re-immigration + mortality (a1 = N; a2 = mean time in study area; a3 = mean time out of study area; a4 = mortality rate)

AIC, Akaike information criterion; N, Population size.

Green turtle site residency and lagged identification rate

Twenty-two individual green turtles were identified and six were re-sighted more than twice. Resighted green individuals were re-identified on 3 (n= 2), 5 (n = 1), 13 (n = 1) and 19 (n = 1) different occasions (Fig.3.6). Two individuals were re-sighted over periods of 2.5 and 3.2 years, respectively (Fig. 3.6). The maximum time between first and last sightings for an individual was 1152 days, and this turtle was reported at two dive sites. Based on the slight differences in model fit (ΔQAIC <2; Table 3.4), three emigration and mortality models (C, D and H) provided an equally valid representation of reality. There was no support for closed population models. The lagged identification rate for green turtles dropped sharply between days 1 and day 6, then remained constant at slightly above zero thereafter.

Table 3.4. Variation in QAIC scores for the eight models fitted against the green turtle data. For best fitting models, population parameter estimates generated from Models C, D and H fitted against lagged identification rate for green turtles, presented with standard error, lower and upper 95% confidence intervals are presented. Whereas models A and B represent closed populations, models C to H represent open populations with varying parameters. Descriptions of the models fitted against lagged identification rate of green turtles (*C. mydas*) are included below.

Model	Green ΔQAIC	Parameter	Value	SE	95% CI lower	95% CI upper
A	13.970					
B	13.970					
C	1.808	a1= emigration rate	0.001	0.165	9.29E-05	0.962
		N= 1/a2	0.204	0.072	-0.072	0.306
D	1.808	a1= N	4.894	3.250	3.266	13.595
		a2 = Mean residence	1020.663	10986.320	196.864	10731.784
E	9.261					
F	9.261					
G	2.582					
H	0.000	a1 = N	0.603	6.189	0.135	36.456
		a2 = mean time in study area	1.187	28.815	-0.737	79.128
		a3 = mean time out of study area	8.317	32.426	0.074	120.115
		a4 = mortality rate	0.001	0.216	2.0E-4	1.254

Model	Description/ Scenario
A	Closed ($a1^{-1}$ = N)
B	Closed (a1 = N)

C	Emigration and mortality (a1 = emigration rate; $a2^{-1}$= N)
D	Emigration and mortality (a1 = N; a2 = mean residence time)
E	Emigration + re-immigration (a1 = emigration rate; a2 $(a2 + a3)^{-1}$ = proportion of population in study area at any time)
F	Emigration + re-immigration (a1 = N; a2 = mean time in study area; a3 = mean time out of study area)
G	Emigration + re-immigration + mortality
H	Emigration + re-immigration + mortality (a1 = N; a2 = mean time in study area; a3 = mean time out of study area; a4 = mortality rate)

QAIC, quasi- Akaike information criterion; N, Population size estimate.

Surface encounters

Boat search effort varied little, in effort or space, across years (Fig. 3.2). The highest search effort across all years was in the inshore area surrounding the boat launching and landing site within Tofo Bay. Search effort was consistent from the northern to southern reefs. Sightings (turtles surface encounters per m^2, SPUE) were low overall. Turtles were generally recorded in association with known reefs, as indicated by dive sites. The highest SPUE occurred close to dive sites in both northern and southern extremes of the study area (Fig. 3.2). Search effort did not correlate with sightings and the area with the highest search effort, Tofo Bay, had the lowest SPUE.

Discussion

The results confirm the year-round presence of sea turtles in the coastal waters and nearshore reefs of Praia do Tofo in southern Mozambique. However, both model analyses and encounter numbers indicate that the number of turtles present on these reef systems was low. In the Bazaruto Archipelago Marine National Park (BANP) (~250 km north), aerial surveys reported 154 turtles sighted over 5 days in May 2008 from a survey area of 174 900 ha (cf. 399 turtles reported in the Tofo dive log from survey area ~ 40 000 ha) (Provancha and Stolen 2008). Their sightings suggest (comparison limited due to varied methodologies) a significantly higher density of turtles occupy the nearshore coastal waters of BANP (4.85E-5 turtles hr^{-1} per ha^{-1} Bazaruto cf. 9.45E-6 turtles hr^{-1} per ha^{-1} Tofo). The greater turtle abundances reported in BANP may be attributed to two differing factors compared to Praia do Tofo; the BANP area has extensive seagrass meadows which still host dugong population, and receives some degree of protection and enforcement as a marine protected area. To compare, in algal dominated coral reef sites of the southern Great Barrier Reef, green turtle density was estimated at 0.45 turtles per ha (Chaloupka and Limpus 2001). Feeding behaviour has been directly observed in green, loggerhead and hawksbill turtles in the Tofo area on dive encounters and within photo-ID encounters submitted (JL Williams 2016 pers. observation). Based on this, I assume that the Praia do Tofo area is likely to be foraging grounds for juvenile turtles, however further evaluation of foraging behaviours specific to each species and age class are needed. No comparative studies from mainland coasts of the WIO region exist. However, daily abundance of foraging green turtles using seagrass beds and reef flats off Mayotte Island, Comoros is greater than reported in this study (Roos et al., 2005; Ballorain et al., 2010). From aerial surveys and snorkelling censuses across a 2.30 ha transect area at Mayotte, mean animals per day was calculated (32 aerial survey cf. 29 snorkel surveys) (Roos et al., 2005). Adding to this, Ballorain et al., (2010) report a turtle encounter rate on the seagrass meadows in N'Gouja bay, Mayotte of 23.9 × 10-4 ± 10-4 turtles m^{-2}. While their methods are not directly comparable to ours, the results suggest green turtle abundance was lower at Praia do Tofo (mean animals per day: 5 or 9.25E-10 turtles hr^{-1} m^{-2}) than at Mayotte, a significant year-round nesting rookery for green turtles (Dalleau et al., 2012) and a known mixed size, year round occupancy green turtle foraging area (with a size bias in animals >80 cm CCL) (Ballorain et al., 2010).

Predictors of Turtle Abundance

Turtle abundance was not strongly influenced by the environmental, temporal or oceanographic variables tested in the GLM. Only 8% of the total variance in turtle abundance could be explained by the GLM, with five significant predictors. Three of these were temporal (year, day of the year and time of day), one oceanographic (visibility) and one environmental (habitat type). One additional spatial variable (dive site) was also a significant predictor of turtle abundance, but was removed from the final model due to a high standard error. Overall the GLM explained a low proportion of the variability in turtle abundance relative to studies on sympatric species. Rohner et al., (2013) documented that 40%, 30% and 24% of total variance could be explained for sightings of reef manta rays (*Manta alfredi*), giant manta rays (*M. birostris*) and whale sharks (*Rhincodon typus*), respectively, within the same study area and from dive logbook data. Rohner et al., (2013) reported year, dive site and water temperature as factors which significantly influenced reef and giant mantas and whale sharks sightings. Low model deviance (8.4%) of turtles and dugongs has also been noted in similar analyses in which oceanic conditions as predictors of megafauna assemblages were used to model aerial survey data at Ningaloo reef, Western Australia (Sleeman et al., 2007). While they reported a weak correlation between bathymetry and relative abundance, where animals were more abundant when a steep change in depth contour occurred (Sleeman et al., 2007), depth was not a significant predictor in my study. The low total variance explained by the model may have been influenced by the multi-specific nature of my analysis (sightings of four turtle species merged together), or a high degree of independent behaviour exhibited by turtles, as has been demonstrated from satellite tagged turtles (e.g. Papi et al., 1997 Hatase et al.,2002, Hatase et al., 2006). Using models to predict and explain the distribution of marine megafauna and how it correlates with oceanographic or bathymetric variables is difficult (Polovina et al., 2004; Piatt et al., 2006; Sleeman et al., 2007). Further complications arise as these models struggle to account for the complexity of animal behaviour, particularly predators (Sleeman et al., 2007). Abundance and distribution of turtles is likely to be influenced by a complex suite of factors, including oceanographic, bathymetric, habitat requirements (food and shelter), deterrents (artificial lighting, heavy anthropogenic use and natural predators) and behavioural (conspecific competition, age class instincts). To improve understanding, it would require higher resolution oceanographic data (spatial and temporal) coupled with long term species specific sightings records in which detailed behavioural information about habitat use and feeding habits is incorporated.

Diving effort was variable among reefs and on different trips to the same reef. Given that oceanic conditions in the area are dynamic and highly variable (i.e. strong currents, low visibility, high surge), the total area of reef covered and direction the reef was surveyed are dependent on ocean conditions. This may help explain the variability in turtle sightings between successive trips to the same dive site, as it is possible that animals are present on a portion of the reef that is not surveyed due to logistical restraints. In addition to this, the dive sites surveyed are part of an expansive chain of reefs that run parallel to the shore and regularly dived reefs comprise a small proportion of total reef area. It is possible that the home range of some of the photographed turtles does not occur in regularly surveyed areas, or that some animals were encountered in the periphery of their home ranges. Greens and loggerheads modify their home range both spatially and temporarily depending on resource availability, environmental conditions (e.g. temperature, depth, productivity of waters) or diurnal patterns (Luschi et al., 2006; Howell et al., 2010; Dalleau et al., 2014, Shimada 2015; Christiansen et al., 2016; Varo- Cruz et al., 2016). The general behavioural-ecological model for Cheloniidae is a gradual shift from pelagic-vagile to benthic-sedentary lifestyle with progressive reduction of home ranges (Godley et al., 2008; Casale et al., 2012), with strong site fidelity evident in some populations (Shimada et al., 2016). Further investigation at this study site is needed to evaluate fine scale movements to investigate if seasonal patterns influenced by temperature (e.g. winter shifts) occur. Given the narrow width of the continental shelf along Inhambane Province, short forays between neritic and oceanic waters could be possible, similar to loggerheads in the Mediterranean, where favourable foraging grounds are exploited by opportunistic animals that use oceanic-neritic edges (Casale et al., 2012).

Some of the relationships among predictors and turtle sightings were intuitive, such as greater visibility resulting in a higher likelihood of observing turtles. Although turtles were present year-round, increased abundance of animals around the summer months could represent an influx to the area for the mating and nesting season (loggerheads or leatherbacks) even though recent (5 yrs) nesting effort in the immediate area has been minimal (<10 nests) (Fernandes et al., 2016). Average carapace size of first time nesters in the loggerhead South African rookery is 84cm (Nel et al., 2013). Based on carapace length estimates supplied by citizen scientists, the majority of in-water loggerhead encounters are of animals of this size or larger. However, I did not detect any changes in turtle size (i.e. where large size turtle bias occurred), regardless of species over the course of the year.

Turtle sightings were significantly influenced by habitat type. Turtle densities were highest in the ‘soft coral’ habitat types which were grouped in the south of the study area, in deeper waters (23 – 30 m). Turtle SPUE from surface encounters was also highest in the southern area in close proximity to these reefs. Abundance of turtles and surface encounter SPUE was also high in the north of the study area, where sites were largely the ‘plate coral’ habitat type. The drivers of the increased abundance of turtles in these habitat types is unclear. In Gorgona National Park, Colombia, atypical feeding behaviour was described at mixed size foraging grounds of the east Pacific green turtle (Amorocho and Reina 2007). They reported reefs comprised of hard and soft corals with sandy benthos and an absence of seagrass meadows, where animals feed mainly on animal matter, with bias towards tunicates (Amorocho and Reina 2007). If a similar feeding behaviour was adopted by green turtle in the Praia do Tofo, this could explain why increased abundance was observed at ‘soft’ and ‘plate’ coral sites. I hypothesize that several factors (habitat quality, habitat diversity, food availability and SSF pressure) may influence the turtles to reside at these sites, rather than the inshore shallow sites, which are “mixed” habitat type. Fuentes et al., (2006) demonstrated a clear dichotomy in juvenile green sea turtles diets foraging in seagrass meadows, patch reefs and reef slopes around Green Island in the Great Barrier Reef, Australia. They showed juveniles have strong preferences for either a seagrass or algal diet and that regular switches between diet preferences was possible (Fuentes et al., 2006). Turtles may have favoured ‘plate’ or ‘soft’ coral habitat types, as it is possible these sites have greater quantities of macroalage or preferred varieties of macroalgal species. Sea turtle abundance is unlikely to be homogeneously spread along the study area, and the spatial dataset found higher densities adjacent to the south and northern reefs. The reason/s for this are unclear. To elucidate this, I suggest spatial characterisation of the benthic habitats in the area be conducted to examine the relationship between habitat types and turtle sightings in detail. The Inhambane estuary system immediately adjacent to the north of the study area provides extensive shallow seagrass meadows and, it is possible that turtle density is higher in these areas (or is more representative of the core habitat area of turtles using reefs in Praia do Tofo). To date, no work has been conducted in the area to determine if turtles (of any species or size class) exhibit avoidance behaviour in the presence of either SCUBA divers or their boats, or artisanal fishers or their vessels.

Photo-Identification & Population Structure

Photo quality, as measured by the percentage of useable photos, varied among species (See example of variation in clarity and angle of photo-ID submissions Fig S2.2). A higher proportion of identifiable photographs were obtained for green and hawksbill turtles relative to loggerheads. The former two species were generally encountered at shallower sites, where ambient light was higher, typically resulting in improved photos in instances where automated point-and-shoot cameras were used. Their facial scute patterns were also markedly more distinct than in most loggerheads. Although Jean et al., (2010) noted that specialist fieldwork and training was not required for successful photo-ID at Reunion Island, the comparatively low photo quality obtained in this study, and consequent low percentage of identifiable images, suggests that dedicated training could be of substantial benefit at this site. Such training could include the development of a series of guiding principles to aid recreational divers, or dive operators, in how to capture and submit suitable photos for analysis, conducting practice sessions with models, suggested camera settings, and explaining the best way to approach turtles without initiating a flight response (Williams et al., 2015/ Chapter 2).

I identified 42 loggerhead and 22 green turtle individuals. Population estimates for both species were small, and encounter rates per dives were only around 24%. However, this was an increase from 8.1% in earlier work in the same area (Williams et al., 2015/ Chapter 2). I think that the higher rate reported here is more reflective of reality, as it was based on a significantly larger presence-absence dive log (n= 720 vs. 1,425). A similar style of population modelling based upon photo-ID of green turtles was conducted in the Philippines (Araujo et al., 2016). Araujo et al., (2016) also present similarly low resighting rates in the majority of their animals encountered. The limited sample sizes available likely mean that mark-recapture model results are more indicative than precise, although the relative daily population estimates (11.6 loggerheads and 4.9 green turtles) do suggest that proportionally more loggerheads were present.

A caveat of photo-ID studies has been the lack of long-term validation for the persistence of scute and scale shapes and colours across decades (Goodman-Hall and McNeill 2013). The longest period of time over which I re-identified an individual was 1.4 years for an adult loggerhead, and 3.1 years for a juvenile/sub adult green. Other studies have re-identified individuals three, four and six and eleven years later (Reisser et al., 2008; Jean et al., 2010; Goncalves and Loureiro 2013; Carpentier et al., 2016 respectively). For greens there is some evidence to suggest facial scale stability exists, although pigmentation patterns can change (Féliz et al., 2010; Araujo et al., 2016; Carpentier et al., 2016). Long-term photo series from known individuals are required to quantify the rates and implications of changes to facial scales, but I think it is reasonable to assume that facial scutes remain stable over the 5-year period discussed here. A caveat to consider is that low resightings rates in loggerheads may be an artefact of identification tool (i.e. lack of suitability in TORSOOI to accurately identify individual loggerhead turtles). To avoid this, visual comparison and manual identification was undertaken for the entire loggerhead dataset to compare against the TORSOOI results. TORSOOI suitably recognised unique details of facial patterns to assign loggerhead identifications. Robust methods testing of the application of this tool for loggerheads would confirm any doubts for future work.

Perception and availability bias

The data also highlight the need to understand perception and availability bias when using observation-based monitoring and citizen science for sea turtle monitoring (Pollock et al., 2006). In particular, I found that photo quality varied across species and was also likely to be influenced by depth (of the diver and turtle) and water visibility. Coupled with this, the GLM indicated that sightings and abundance were linked to several factors that relate more to when and where turtles are available, such as time of day or year. Imperfect detection is known as availability bias and can be addressed by experimentally assessing sightability under a variety of environmental conditions (Fuentes et al., 2015). Perception bias could be linked to expertise or experience. Understanding the influence of bias, such as availability and perception, in citizen-science based species monitoring is a key question for future research.

Movement Patterns

Green turtles, with a modelled mean residency time of 1021 days, were present on Inhambane reefs for longer periods of time than loggerhead turtles, which had a mean residency of 246 days. A small number of green turtles demonstrated strong site fidelity, with some individuals resighted between 13 and 19 times at a single dive site over the duration of the study. Dive log data identified most of these individuals to be juveniles. Juvenile green turtles have been well-documented to be resident in shallow coastal waters (Meylan et al., 2011; Ballorain et al., 2010; Scott et al., 2012). Thus, the likelihood of encountering resident animals in their home range can be relatively high. In contrast, although loggerhead turtles were more frequently encountered than greens (0.20 and 0.15 turtles per hour, respectively), they were rarely resighted. Dive log data showed that curved carapace size classes of ≥ 70 cm were present, suggesting that both sub-adult and adult loggerheads use the area. I advise some caution in interpreting the carapace length data presented, as they are estimates rather than measurements and future work should adopt more precise estimation techniques (described in Houghton et al., 2003) or continue to expand and evaluate the laser photogrammetry dataset. Several accounts exist of post-nesting loggerhead turtles using neritic waters of Mozambique (Hughes 1974; Luschi et al., 2006 and Pereira et al., 2014c). Fidelity to these post-nesting foraging grounds and the migratory routes used to reach them have been reported from other loggerhead populations (Schofield et al., 2010). Pereira et al. (2014c) documented the variability of foraging destinations in northward post-nesting migrations (potentially shuttling migrations described in Luschi et al., 2006) from three satellite tracked female loggerhead turtles swimming from natal beaches in the Ponta D’Ouro Marine Partial Reserve in the extreme south of Mozambique. One animal travelled north into Macaneta and Xai Xai, an area Pereira et al.

(2014c) believed to be its resident foraging ground (250 km south of present study area). Dangers of artisanal fisheries interactions were also evident in the second animal which was caught by turtle hunters 20 km south of Praia do Tofo (Pereira et al., 2014c). Some mature loggerhead turtles may therefore have permanent feeding grounds in coastal waters within Inhambane Province, with others being transient visitors returning to natal beaches or on their way to more distant feeding grounds (e.g. Tanzania, Madagascar) (Luschi et al., 2006; Pereira et al., 2014c). The data types used in this study give a general indication of site fidelity and movements, but the absence of fine scale spatial and temporal data prohibits the calculation of reliable estimates of home ranges. Acoustic, radio-telemery and satellite tagging of animals using this area would be a logical next step for progressing knowledge of habitat use and movements.

Potential interactions with small-scale fisheries

Sea turtle populations near Praia do Tofo are relatively small. Given the year-round presence of turtles documented here, their abundance in shallow (<35 m) nearshore reef areas, and the long residency periods of some individuals, I speculate that these turtles are highly susceptible to capture by SSF, either as bycatch or as illegal target species. Resighting rates, particularly of loggerhead turtles, were low. Population models indicated a high degree of movement into and out of the area. I am unable to ascertain if low resightings are due to high transient behaviours or if high mortality rates from SSF occurs in the study area or the surrounding region. However, in Chapter 4 I report on regular mortalities (n = 353, 2009-2016) from targeted hunting and bycatch from artisanal fisheries in the same area. This number of dead turtles is on par with the total number of live turtles sighted throughout the entire dive log, suggesting that SSF may be a serious threat to turtles in this region. Rates of illegal take and use are suspected to be high within Mozambique (Louro et al., 2006), and within the SWIO all sea turtle species are highly vulnerable to artisanal fisheries bycatch (Bourjea et al., 2008; Bourjea 2015; Kiszka 2012). It is unclear whether the low population density in the area is a consequence of this hunting over the past decades, but future comparison with areas with lower contemporary anthropogenic pressure would be useful. Broadening citizen-science data collection to include the activity of fishers would be particularly valuable.

Conclusion

This chapter synthesizes three different datatypes to reveal novel information on the nearshore habitat use, abundance and distribution of green and loggerhead sea turtles in the Praia do Tofo area in southern Mozambique. Both species use the area year-round, as a foraging ground for some immature green turtles and transient habitat for other life stages. Modelled population sizes, surface encounter and dive encounter rates all suggest that the contemporary turtle population in the area is small. However, limitations in the methodology prevent accurate assessment of abundance and the opportunistic nature of data collection have limited a robust evaluation of spatio-temporal patterns. While sightings trends were stable over the limited time series of the available datasets, they were also very low and thus I am concerned that high fishing and hunting pressure on these inshore reefs is a likely threat to these local sea turtle populations (Louro et al., 2006). Human impacts are likely to be higher on green turtles, which are more resident (and potentially favoured for their meat (Chapter 4) than loggerhead turtles. The relatively higher number of loggerheads sighted means that fishing-derived mortality here could also have broader impacts on the Western Indian Ocean stock of this species.

Chapter 3 Summary

- In this chapter I used a five-year dive log, photo-identification (photo-ID) and surface encounter datasets to investigate the abundance, individual movements and distribution of sea turtles along 40 km of coastal reefs in southern Mozambique.
- A generalised linear model was constructed with turtle sightings as the response variable. Habitat type, year and day of the year, as well as underwater visibility, were significant predictors of turtle sightings. However, only 8% of the total variance was explained by the model, indicating that other variables have a significant influence on turtle movement and distribution.
- Photo-ID differentiated 22 individual green turtles (*C. mydas)* and 42 loggerhead turtles (*C. caretta)* from 323 photo-ID encounters.
- A majority (64%) of the photos could be identified to individual.
- Although residency times of up to 1152 days were calculated for juvenile green turtles, a low overall resighting rate indicates that individual turtles either had large home ranges or were transient in the area.
- Surface encounter data revealed a preference for nearshore shallow waters and an increased abundance close to reef systems.
- Sea turtles with preferences for shallow, nearshore habitats are likely to have an increased risk of encounters with opportunistic and targeted artisanal fishers who catch sea turtles.

Chapter 4

Quantifying the illegal take and use of sea turtles in Mozambique.

Based on findings of sea turtle habitat preferences to nearshore coastal waters in Chapters 2 and 3, this chapter was designed to investigate and quantify the threat of illegal take of sea turtles. Here I define illegal take as the prohibited and unregulated retention of sea turtles (either dead or alive, whole or parts) captured using any means (harpooning, long-lining, gillnetting etc.) resulting from intentional or opportunistic fishing practices and encompassing the take of foraging and nesting turtles. While illegal take of turtles is considered to be a widespread problem throughout the SWIO and well known to occur throughout Mozambique, quantitative studies are lacking. This chapter presents the most comprehensive investigation undertaken to date into the spatio-temporal patterns of illegal take of sea turtles to date for Mozambique.

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Abstract

The life history characteristics (e.g. long lived, late maturity) of most marine megafauna species are conservative and render them unsuitable for intensive or sustained harvest. Targeted or opportunistic harvest of sea turtles occurs throughout much of their range and this has led to significant population declines. Illegal harvest of sea turtles along the Mozambican coastline has been routinely reported, but remains largely undocumented. To collect evidence of illegal take of sea turtles between 2009 and 2016, I used beach transects to survey along the sand dunes within Inhambane Province and a literature review for the country. In addition, I investigated the spatial overlap between sea turtles and small scale fisheries (SSF) by calculating interaction risk for the area around Praia do Tofo in Inhambane using 2012- 2015 data. Over the total study period I detected 362 individual mortality events with contextual evidence to suggest incidents of illegal take, which impacted all five sea turtle species present in the country. Records were distributed along the entirety of the Mozambican coastline. In Praia do Tofo, a hotspot in Inhambane Province, I detected 195 remains (carapace, plastron or bones only) of three species (*C. mydas* 32%, *C. caretta* 18%, *Eretmochelys imbricata* 1%) from 57 beach transect surveys. Almost half of all remains (49%) could not be identified to species level. An additional 167 records of mortality caused by illegal take were collated from literature records. An additional ten whole or partially decomposing turtle carcasses were detected and identified as stranded animals during the study period within Inhambane Province. Bycatch, sickness, or plastic-ingestion related strandings were not included in this analysis. There was considerable overlap between SSF and sea turtle presence around the

Praia do Tofo area. The areas of highest risk to turtles were those that were accessible to people; inshore (<4 km from coast), adjacent to coastal headlands, or close to reef systems. Over the study period (2011 - 2015) I observed the density of spear fishers and fishers deploying gillnets to increase significantly

Introduction

Sea turtles face a number of threats since their habitats intersect with human activities. Threats include by-catch from commercial and artisanal fisheries, nesting beach modification, plastic ingestion, and entanglement (Donlan et al., 2010; Fuentes et al., 2013). Low reproductive potential and delayed sexual maturity make all sea turtle species susceptible to population decline (Musick 1999; Heppell et al., 1999). Although sea turtles are legally protected across much of their range, illegal take is a common and widespread threat throughout most of their range (Campbell 1998; Campbell 2003; Mancini et al., 2011b; Guebert et al., 2013; Bourjea 2015). Quantifying this take, which frequently occurs in remote areas of developing countries is difficult (Salas et al., 2007; Soykan et al 2008; Humber et al., 2011).

Five species of sea turtles use Mozambican waters and have been protected by national laws since 1965 (Louro et al., 2006). Mozambique is also a voluntary signatory to international treaties, such as Convention on International Trade in Endangered Species (CITIES, since 1981(CITIES 2016), the Convention for Migratory Species (CMS 2016a) and the Memorandum of Understanding on the Conservation and Management of the Marine Turtles and their Habitats in the Indian Ocean and Southeast Asia (IOSEA-MoU, since 2008). However, enforcement of the current legislation aimed at protecting sea turtles is lacking and outside of marine conservation areas enforcement is almost non-existent (Louro et al., 2006; Pereira et al., 2014b).

Difficulties of monitoring illegal take and use.

Defining direct, opportunistic or incidental take by fishers is often challenging in itself (Fuller et al., 1992; Godley et al., 2004; Humber et al., 2014). For instance, small scale fishers though not specifically targeting turtles often take turtles opportunistically on fishing trips or retain turtles caught as bycatch (Hoyle 1994; Fleming 2001; Petro et al., 2007; Alfaro-Shigueto et al., 2011). Fishing effort is also highly variable and can range from specialised hunters targeting turtles to groups of occasional and regular fishers who occasionally catch or retain accidentally caught turtles (Godley et al., 2004; Humber et al., 2014; Chapter 5). In this chapter I define illegal take as the prohibited and unregulated retention of sea turtles (either dead or alive, whole or parts) captured using any means (harpooning, long-lining, gillnetting, etc.) as a result of intentional or opportunistic fishing practices. This also included the take of foraging and nesting turtles. Classifying the cause(s) of sea turtle mortality from small scale fisheries (SSF) is complex, and often not definitive because of the diverse and varied nature of SSF (Moore et al., 2010). For example, in the literature the bycatch of turtles caught using gillnets, long-lines, beach and purse seines and fish traps is generally not considered as illegal take (Bourjea et al., 2008; Kiszka 2012; Casale and Heppell 2016). Rather it is classified as accidental take, because it is assumed the target species of the fishery is not turtle. However, if turtles which are caught accidentally are subsequently kept to be sold or eaten, this can, depending on the legal situation of a country constitute an illegal activity. One of the key issues in Mozambique (and Madagascar; Humber et al., 2011) is that SSF techniques (particularly gillnetting or long-lining, or other non-selective fishing gears) are adopted by fishers to target a multi-species marine fish and megafauna fishery (i.e. sharks, turtles, dugong, rays, cetaceans). Typically, sea turtles captured using gillnets or longline is classified as bycatch or accidental take, because the target catch is not turtles. However, within developing nations, SSF are diverse and fishers behavour is varied, often driven by large scale socio–economic drivers, such as poverty and food security (Finkbeiner and Basurto 2015; Berkes et al., 2001). Thus, the scenario of turtle 'bycatch' and illegal take is more complicated than the generally accepted 'accidental take' definition because fishers in Mozambique retain bycatch. The prevalence and consequences of this intentional, planned megafauna fishery has not been thoroughly investigated in Mozambique or the SWIO.

Although illegal take from SSF has not been well reported or quantified, the potential rates of mortality resulting from SSF (globally) are thought to be high (Alfaro- Shigueto et al., 2011, Humber et al., 2011, Casale 2011; Humber et al., 2016). Within the Western Indian Ocean up to 85% of all sea turtle mortalities are thought to be from illegal take (Muir 2005). Though more commonly applied in terrestrial settings, it is possible to derive trends of illegal take from enforcement records, however it may not portray actual incidences because such data require considerable surveillance (Knapp et al., 2010; Kahler and Gore 2012). Given the realities of severely limited enforcement and surveillance efforts within developing countries and/or countries with extensive coastlines and offshore islands, such as Mozambique, alternative methods to effectively detect and monitor illegal take need to be considered. Previous investigators have used direct observations (Kotas et al., 2004; Alfaro- Shigueto et al., 2011; Humber et al., 2011) and/or interviews (Walker and Roberts 2005; Mancini et al., 2011b; Hancock et al., 2016; Poonian et al., 2016) to quantify the rate of illegal take in SSF. Quantitative studies focusing on rates of illegal take from targeted hunting are rare and either rely on detecting carapaces for counts or interviews directly with hunters (Koch et al 2006; Mancini et al., 2011b; Poonian et al., 2016). However, all these methods tend to underestimate rates of capture and mortality due to covert behaviours adopted by fishers, the capture techniques employed and fishers underreporting capture rates to reduce the likelihood of negative implications to their livelihood.

Illegal take in SWIO and Mozambique

Illegal take has been documented through most of SWIO and is well known to occur within Mozambique (Louro et al., 2006; Chapter 4). Fishers from across the SWIO region have been reported to retain bycatch (Okemwa et al., 2004; Mellet 2015; Kizska 2012). Current knowledge suggests Madagascar has the highest rates of illegal take of sea turtles in the SWIO (estimated at 11,000 – 16,000 turtles annually from Toliara Province: Humber et al., 2011). The rate of illegal take across the SWIO is thought to have remained constant since the 1970's (Hughes 1970, Frazer 1980, Humber et al., 2016). Despite regional turtle population increases (Lauret-Stepler et al., 2007; Bourjea et al., 2007), Madagascar's nesting turtle populations have either remained stable or decreased (Humber et al., 2016). Further, Humber et al., (2016) proposed that nesters are remnants of historically larger populations and that regional population growth has enabled/sustained high rates of illegal take without evidence of population crashes. Many similarities occur between Mozambique and Madagascar in terms of their socio-economic conditions, the pressure they place on their marine environments from SSFs and the patterns in the motives and drivers for illegal take (Chapter 5). Data from Mozambique is scarce and opportunistic, yet Louro et al., (2006) proposed Tofo, Inhambane in southern Mozambique as a potential hotspot for illegal take. Consequently, in this chapter I investigated the quantities of illegally used sea turtles at; 1) the proposed hotspot; 2) at a national scale, and 3) evaluated the consequences of illegal take on sea turtle populations at the small (Tofo) provincial and regional (SWIO) scales. Using the Tofo area as a case study I also evaluated the abundance and use of SSF in nearshore waters and evaluated the spatial interactions between fishers and turtles to consider the risk of illegal take.

Methods

Study site, MPA's and enforcement.

There are five marine protected areas (MPA) presently within Mozambique covering 3% of its territorial waters (World Bank 2014); Ponta D'Ouro Partial Marine Reserve (PPMR), Sao Sebastian, Bazaruto Archipelago National Park (BANP), Primerias and Segundas Marine Protected Area (PSMPA) and the Quirimbas Archipelago MPA (Fig. 4.1). With the exception of PPMR, where enforcement of sea turtle protection laws and fishing activities occurs through regular patrol efforts, the other MPA's provide little protection for sea turtles (Pereira et al., 2014b). Sea turtle patrols only effectively cover ~ 4.6 % of the coastline during nesting seasons (Fernandes et al., 2016). Enforcement and conservation monitoring is either absent or inadequate across major portions of the mainland coast due to logistical difficulties or inaccessibility and financial limitations and/or localized politically unrest). Management and monitoring of populations (foraging or nesting) and illegal take on the approximately 50 Mozambican offshore islands is exponentially more challenging. The suspected hotspot for illegal take in the Tofo area, is not included in any current MPA. The Tofo area has been identified as a significant area for marine biodiversity, reflected in its nomination as a marine world heritage site (Obura et al., 2012) and one of the 21 priority sites in the East African Marine Ecoregion (EAME) region (EAME 2004). Tofo and Inhambane Province increasingly rely on a growing ecotourism industry to sustain the local economy, which relies on healthy marine ecosystems to enable tourists to have encounters with or observe a variety of wild marine megafauna species.

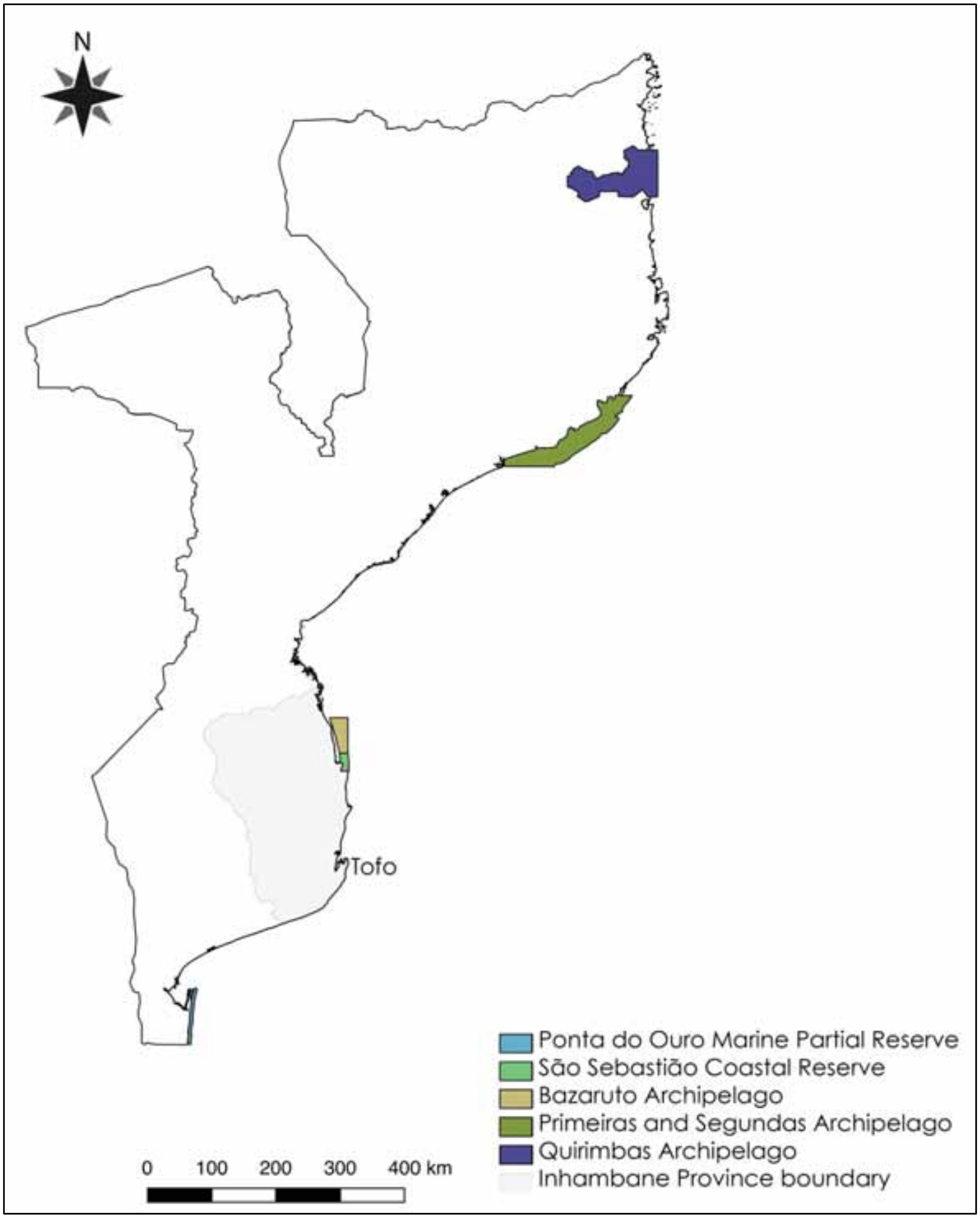


Fig. 4.1. Marine protected areas (n = 5) in Mozambique with Inhambane Province, our study site for illegal take transects, shown in grey.

Beach transects

Surveys of the sand dunes were conducted during 2009-2016 to monitor for evidence of illegal take of sea turtles (whole turtle carcass, carapaces or bones). Transect effort was focused at Tofo (−23.51° S, 35.23°E), Inhambane Province, southern Mozambique (Fig. 4.1). Surveys were conducted on foot in the primary and secondary dunes running parallel to the ocean. Most survey efforts were directed towards the Tofo area and along the Inhambane peninsula, in an attempt to monitor and confirm its status as a suspected hotspot for illegal take. In total 57 surveys were completed between 2009- 2016 with location and survey distance varying between 1 km – 7 km, depending on the location. Survey duration was not used as a metric to standardise survey effort given the variability in walking pace dictated by the very hot environment and requirement to repeatedly climb steep sand dunes. Thus, I present records of sea turtle mortality as turtles km^{-1}.

Determining the cause of sea turtle mortality arising from illegal take, or accidental take is challenging (and often not possible) and is likely to largely depend on circumstantial evidence in the environment (i.e. where the remains were found (beach or in-water), evidence of puncture holes in the carapace or fishing gear used). This southern Mozambican area has a distinct lack of large terrestrial predators. Domestic dogs are the only predator like to be present in the area however their bite marks to a carapace are unlikely to resemble the distinctive hole of a harpoon puncture.

Determining if bycatch in gillnets or long-lining was accidental or targeted is impossible without knowing the intention of the fishers, or contextual environmental information about the fishing area, especially if illegal use occurs regardless of the capture scenario. Where possible, contextual environmental information was recorded with each mortality event; ie: whether the remains were found within temporary fishing camps and what type of fishing gear was located. Carcasses from stranded turtles were not included in this analysis. It was not possible to determine the frequency of when stranded whole carcasses were seized by fishers, dragged up into the dunes, and being dissected for illegal use. Therefore, there are potentially a few occurrences of carcasses being using in this way and thus included in counts of illegal take. Dead stranded turtle carcasses remained whole and were found low on the beach, typically below the high tide line. Strandings within Inhambane Province throughout the study period were infrequent (n = 10). Additionally, of the dead animals that were found stranded on the beach, none had obvious signs of entanglement, vessel strike or damage to suggest they were discarded bycatch. Given that fishers take and consume stranded carcasses (documented by Okemwa et al., 2004; Bourjea 2012; Mellet 2012), it is unlikely that bycatch animals would be frequently discarded and thus this may explain the low level of fisheries related strandings in the area. For this study I classified remains as being illegally taken when all of the flesh, flippers and skull was cut away and removed from the site, leaving only carapace remains behind. Records of illegal take were found in the sand dunes, usually in the dune swale between fore/primary/secondary dune, often within close proximity to a fishing camp.

Illegal take of nests and nesting females

Nesting effort data from 90 km of beach between the Inhambane peninsula to Zavora was collected between 2011- 2016. Nesting activity was opportunistically reported to me by the general public or project partners.

Where possible, nesting activities of loggerhead or leatherback, or events not confirmed to species, were inspected in the field to confirm the activity as a turtle nest and monitored over the incubation period (~ 60 days) to determine hatching and emergence success. Data on false crawls or incomplete nesting attempts are not presented. According to standard nesting beach monitoring protocols (i.e. Miller 1999), nesting events were classified (by myself or an experienced researcher) as; 1) successful to hatch, 2) poached (illegally harvested), 3) unconfirmed status (not possible to conclude if nest had been illegally harvested or hatched, as evidence to confirm either could not be located post incubation period), 4) washed away by storms, cyclones or spring tides, and 5) nesting female being illegally harvested prior to laying. Only where illegal take of a nesting female could be conclusively proven have these incidents have been reported and these numbers are likely to be conservative estimates.

Literature review

A literature review was conducted to identify quantitative reports of illegal take of sea turtles within Mozambique which could be attributed to artisanal fishing or targeted hunting rather than bycatch from fishing fleets (artisanal or commercial). The primary source of information was the national status reports for sea turtles (e.g. Fernandes et al., 2016a; Fernandes et al., 2015). To avoid double counting records, I only considered reports in the literature review outside of the Tofo- Inhambane area. I was part of the team established to compile these status reports each year and I am confident duplication (double counts) has not occurred for records within Inhambane Province.

Data analysis for transect and literature review datasets.

All carapace length (CCL) data were tested for normality using Shapiro-Wilk tests. Based on box, residual and q-q plots, data were found to not be normally distributed. Hawksbill data was excluded from calculations because of restricted sample size (n = 2). Kruskal-Wallis rank sum tests were used to compare the CCL between species, and pairwise comparisons using Tukey and Kramer (Nemenyi) tests were conducted for interspecies differences in CCL. Descriptive statistics (mean and standard deviation) were also calculated for species CCL data.

In order to compare the illegal take to the population size (per species), the number of individuals taken per species was expressed as a percentage of the number of nesting females annually (based on SWOT online turtle database; Kot et al., 2013; presented in Mellet 2015). The average estimate of the number of nesting females annually was the only metric comparable across the region for all species that could be used to indicate proportional impacts.

A vector GIS file of the Mozambican coastline was spilt into 100 km segments (n = 70 segments) excluding offshore islands (downloaded from AWC geoMapping server). The total number of sea turtle mortality records per segment was derived. Given the opportunistic style of data collection, the data are positively biased towards segments where mortalities have been reported. Records of mortality exist in only 18/70 segments.

Annual estimates of mortality or illegal take on a national scale are not possible to calculate given the variability in search effort. Efforts to quantify mortality per km^{-1} of coastline were hindered by coastline paradox (scale and detail in which coastline is denoted thus changing its total length)

(Richardson 1961). I chose to conduct the analysis using a detailed coastline GIS file, which results in a total coastline length of 7000 km although Mozambique's coastline is typically reported as 2 770 km (e.g. Pereira et al., 20014b).

Spatial interactions between turtles and small scale fishers.

I used turtle sightings per unit effort (SPUE) data (presented in Chapter 3) to look at the overlap between small scale fisheries and turtles. GPS tracks of survey effort covered by dive boats were available from February 2012 to September 2015. Additional records were captured during ocean safaris, (boat trips sent in a southward direction to search for whale sharks and other marine megafauna at the surface). The dataset consisted of 656 tracks in totalling 28 231.53 km (2012 (n = 167, 7336.05 km), 2013 (n = 191, 8910.39 km), 2014 (n = 142, 6391.73), and 2015 (n = 156, 5593.36 km)). Waypoints marking turtle encounters at the surface were sorted and mapped per year (merging all records regardless of species). Georeferenced records of fishing activities (spear fishers, gill nets, or small wooden boats/ kayaks, long-lines) were also documented to compliment this dataset. For spatial analysis, all fishing types were grouped together as records of fishing threat. While the individual impact (or risk) of fishing gears is likely to be variable, for the purpose of this spatial analysis I have treated them as all having an equal likelihood of impacting turtles (based on our results from the interview data with local fishers (Chapter 5)).

To standardize this data set, search area was calculated by adding a 30 m buffer (15 m to represent either side of the boat) around all boat tracks per year, with the total area of this being compared between years (Williams et al., in review 2016). Fishing surface encounters were converted to scores representing presence-absence in a 500 m x 500 m square gridded area of the study site (40 km long, 6 km wide). Search effort per grid cell and fishing records were used to calculate a fishers SPUE. Given that no significant difference in the grids of SPUE across years were detected, I aggregated yearly datasets (2012-2015) to assess fishers SPUE and 'risk to turtles' over the entire study period. 'Risk to turtles' was calculated by multiplying the turtle SPUE (Chapter 3) value per grid cell by the fishers SPUE.

Mean annual SPUE was evaluated for gillnets, spearfishing and surface encounters of turtles. Linear regression analysis (using R – R Core Development Team 2016) was completed to evaluate if either abundance of fisheries type or turtles was correlated with year. GPS coordinates for fishing camps were recorded during beach transects within Inhambane Province.

Results

Remains of a total of 195 sea turtles were found across 57 survey events (mean 3.4 individual turtles found per survey). Of the five sea turtle species inhabiting Mozambican waters, the carapaces, plastrons, bones or full carcasses of only three species were found. Approximately half of the remains (old bones) (49%, n = 93) could not be positively identified to confirm species. Of those identifiable, the most abundant remains were of the green sea turtle (*C. mydas*, n = 65), followed by loggerhead sea turtle (*C. caretta,* n = 34) and hawksbill turtles (*E. imbricata,* n = 2). Morphometric data were collected for 47% (n= 92) of cases (Fig. 4.2).

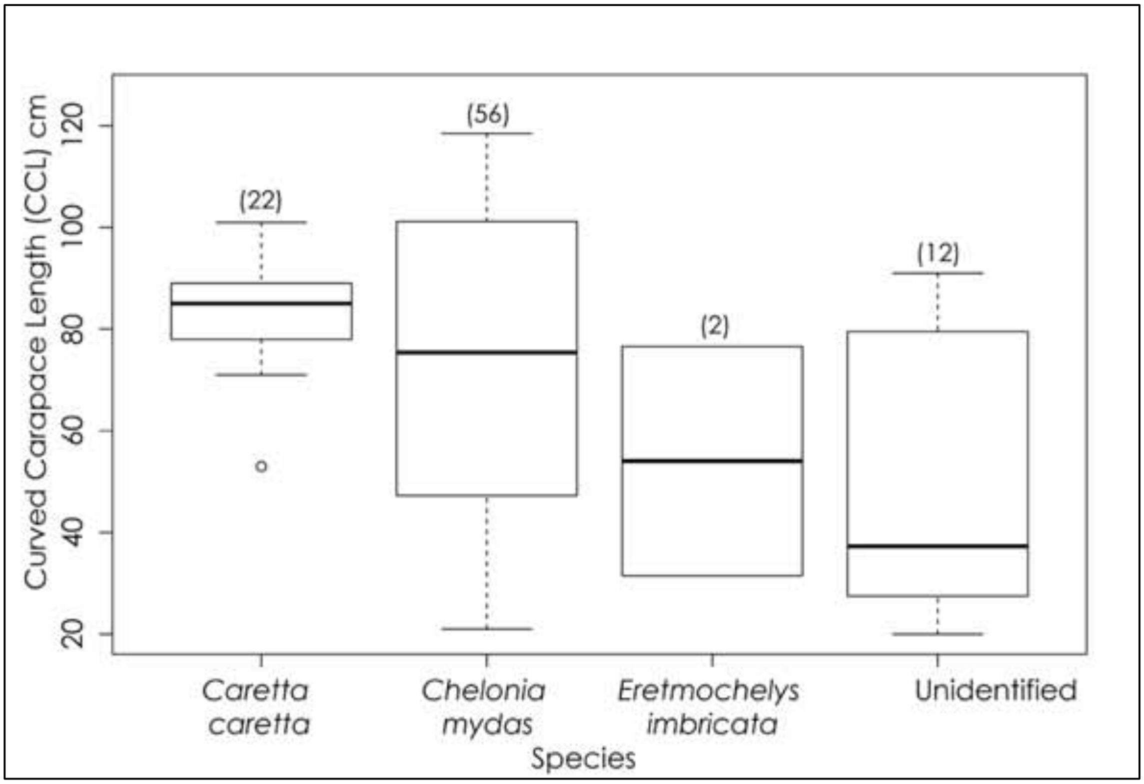


Fig. 4.2. Linear descriptive statistics from curved carapace length (CCL) of turtle carapaces detected in Tofo area, according to species where carcass morphometric records could be collected (n = 92). Plot shows range and spread of CCL data between the 25th and 75th percentiles, with bold line representing the median.

Illegal take of all size classes was detected for green turtles (21 to 118 cm) and a similar range in size was reported for records that could not be assigned to species (21 to 91 cm). Only two records of hawksbill turtles were detected, both were immature sized (Van Buskirk and Crowder 1994). No evidence of small loggerhead turtles was detected, only large sized animals were found, likely to represent sub-adult or adults (Table 4.1) (Van Buskirk and Crowder 1994). Puncture holes consistent with spears were evident in 15 carapaces.

The full carcasses of ten animals (2 juvenile sized *E. imbricata*, 5 juvenile to adult sized *C. mydas*, 2 adult sized *C. caretta*, 1 adult sized *D. coriacea*) were found along the tide line during the study period. These animals were found in advanced stages of decomposition (bloating and rotting tissue) and cause of death was unknown.

Table 4.1. Carapace morphometrics of turtle remains detected in transect surveys in Tofo area.

Species	Total number of remains	Number of remains measured	Mean CCL (cm)	Min CCL (cm)	Max CCL (cm)
Loggerhead	34	22	82.87 ± 9.89	53.00	101.00
Green	65	56	73.29 ± 28.22	21.00	118.50
Hawksbill	2	2	54.13 ± 31.89	31.50	76.76
Unidentified	93	13	50.13 ± 27.56	21.00	91.00

Significant differences were detected in the CCL between species (Kruskal-Wallis chi-squared = 11.2636, df = 3, $p = 0.010$). Species CCL was significantly larger in greens ($p = 2.6E-14$) and loggerheads ($p = 2.8E-8$) than unidentified species.

Another 167 records of illegal take outside of our Inhambane survey areas were obtained via literature records. The literature review confirmed records of illegal take occurring in all five species of sea turtle that use Mozambican waters were subjected to illegal take and that the activity is evident along the entire coastline.

Using the cumulative records from beach transects and the literature review, Inhambane Province had the highest rates of turtle mortality (n = 225) followed by Nampula, Maputo, Gaza, Cabo Delgado Provinces respectively (Fig. 4.3). No data were available for the two central provinces representing the 'swamp coast zones' of Sofala or Zambezia (Fig. 4.3).

Cumulative impact (sum of cases) of mortality events are presented per 100 km coastal segment. Of the 70 segments that represent Mozambique's coastline, 52 had no records. Inhambane Province was the best-surveyed, with records of turtle mortality reported in 7 of its 12 segments. The highest frequency of mortalities was reported along segments of the Inhambane Peninsula (i.e. multiple 100 km segments with mortalities). However, the highest density of mortality events was reported from a single 100 km segment in the Primeiras and Segundas MPA, Nampula Province (Fig. 4.3). In the 18 segments where turtle mortality were reported, numbers ranged from 0.01 turtles km^{-1} to 0.82 turtles km^{-1}. Mortality events occurred within all five marine protected areas.

Two segments on the Inhambane peninsula contained 60.5% of mortality records for the province. In this hotspot, mortality rate was 0.68 turtles km^{-1}. However, if I account for the 'coastline paradox', the linear distance of the peninsular is ~ 100 km rather than 200 km which would lead to a mortality metric of 1.36 turtles km^{-1}.

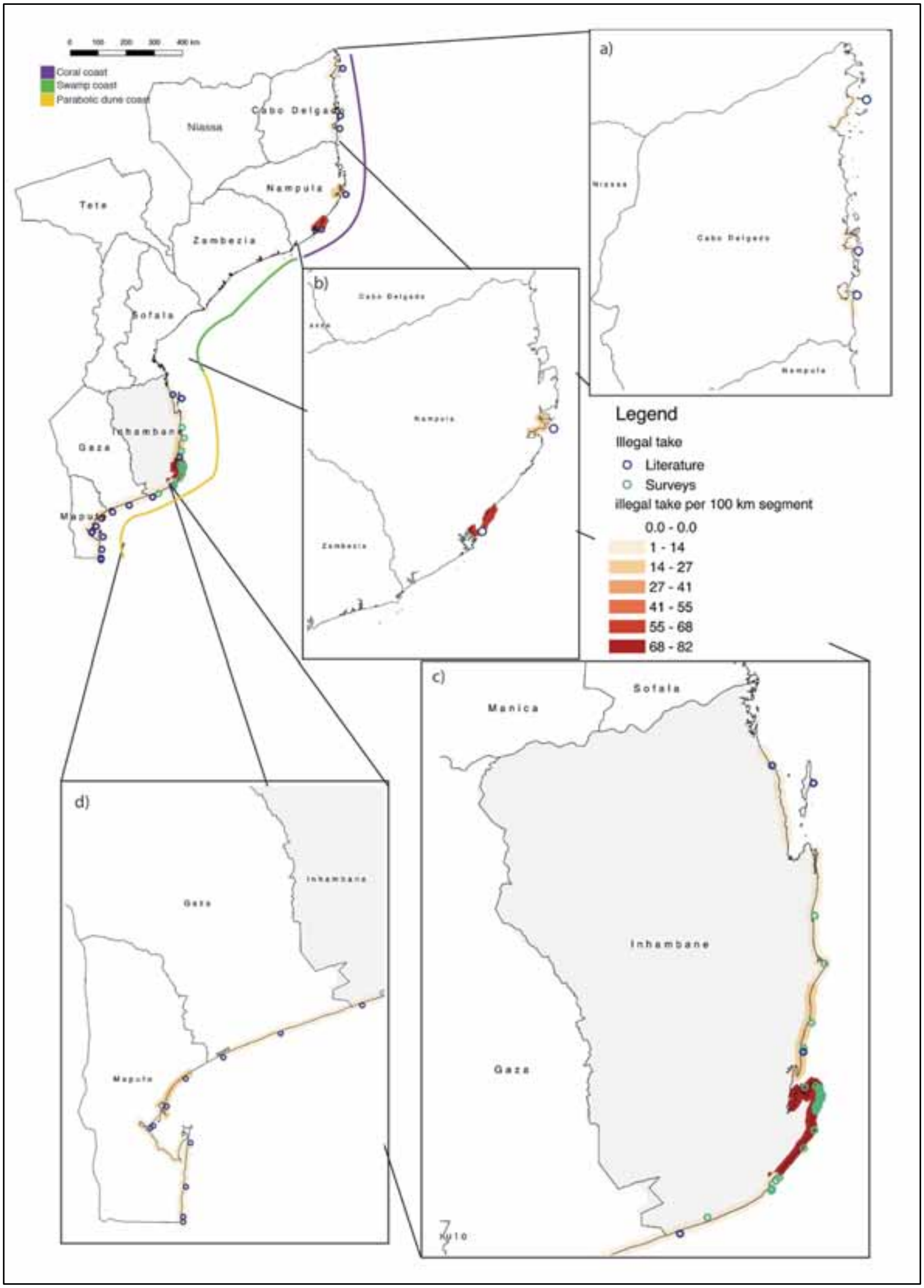


Fig. 4.3. Mortality records per 100 km segment of coastline (excluding islands) between 2009 - 2016. Major habitat types (coral, swamp and

parabolic dune) of the Mozambican coast are shown on national map. Source of mortality records, field survey (green) or literature(blue)are displayed as colour coded circles. Inset maps display all provincial areas where mortality records exist; a) Cabo Delagdo (n = 3), b) Nampula (n = 81), c) Inhambane (n = 225) and d) Gaza (n = 11) and Maputo Provinces (n = 42).

Mortality records for the five species of sea turtles distributed in Mozambican waters exist. Analysis of the spatial distribution of mortality events is constrained by the bias of increased sample effort along the parabolic dune coast. Temporal biases in survey effort confounds the evaluation of detailed temporal patterns or seasonality of mortality events. However, abundance in mortality records are biased towards the summer season when seasonal conditions enabled access to the field sites to undertake surveys (Oct-Mar) (Fig. 4.4.).

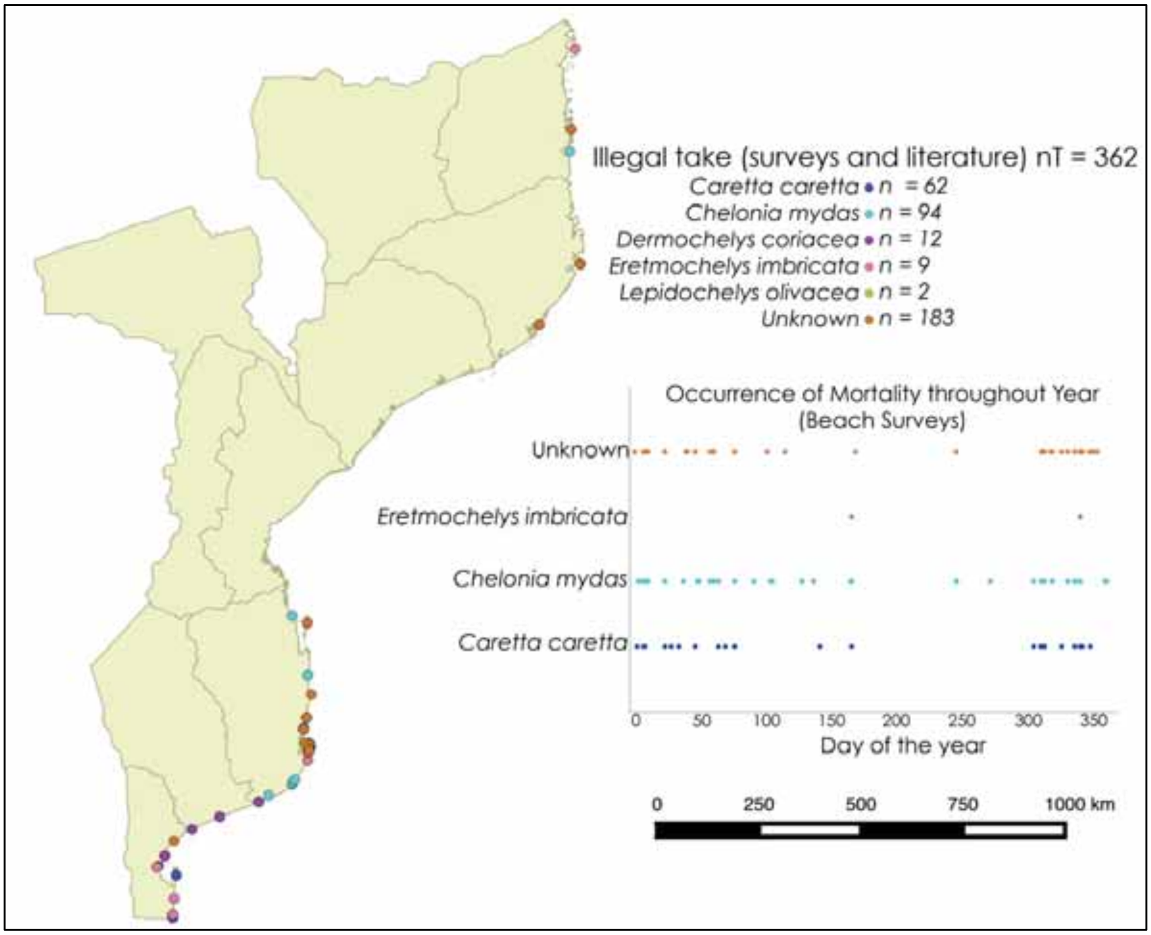


Fig. 4.4. National distribution of illegal take of sea turtles by species from beach surveys and literature review between 2009-2016. Insert displays temporal distribution (day of the year) of the detection of each mortality event for the beach survey dataset.

Illegal take of nests and nesting turtles

Between 2011 and 2016, a total of 32 nesting events were confirmed along a 90 km stretch of beach from Tofo south to Zavora. Loggerheads were the most abundant nesting species, ($n_T = 14$) but confirmed hatching success was low (n = 4, 28 %). Leatherbacks nested in equally low numbers ($n_T = 11$) with low success (n = 3, 27 %). A small proportion of nests were not identified to species ($n_T = 7$, n = 2 hatching) but exhibited similarly low levels of success 28 %. Mean number of nesting events between 2011-2015 were similar between species (2.6 ± 1.95 (SD) loggerhead cf. 2.2 ± 2.28 (SD) leatherback and unidentified 1.2 ± 1.64 (SD)). Mean number of confirmed successful nests were consistently low regardless of species (loggerhead 0.8 ± 0.45 SD, leatherback 0.6 ± 0.89 SD and unidentified 0.4 ± 0.89 SD). Mean number of nests illegally harvested (poached) were comparable to success rates (0.5 ± 0.89 SD loggerhead nests, 0.8 ± 0.84 SD leatherback and 0.2 ± 0.4 unidentified). Mean average success of a nest, regardless of species was 28 %.

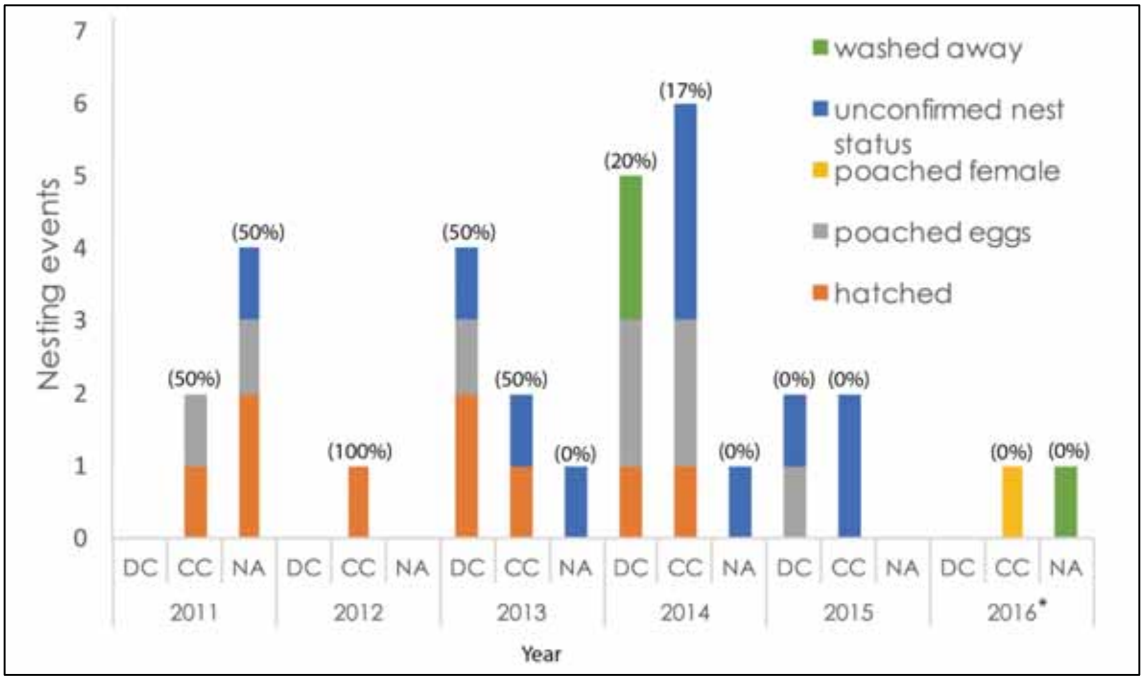


Fig. 4.5. Total number of nesting events (n = 32) of leatherback (DC), loggerhead (CC) and nests not identified to species (NA) for the beaches of Tofo- Zavora (~ 90km), Inhambane Province between 2011- 2016. Nesting events colour coded to represent fate of the nesting attempt (successful nest confirmed to hatch, eggs taken, female taken, unconfirmed nest status or nest washed away by tides or cyclones). Data captions represent the percentage of nesting activity that was successful (n_T = 28 % successful of all nesting activity).

Comparison of illegal take to nesting population sizes

The quantity of illegal take varied among species (Table 4.2). Illegal take represented as a portion of the annual number of nesting turtles was also variable in its impact among species, which was lowest for olive ridley turtles at 0.02 % and highest for leatherbacks at 1.5 % (Table 4.2).

Table 4.2. Species composition of illegal take detected from records in the literature, in total (literature and surveys), estimated annual nesting female population per species and illegal take as a percentage of the estimated annual nesting turtle population from the SWIO.

Species	Total number of remains in literature *	% species compo-sition	Total number of remains (literature and surveys)	Nesting female population	illegal take as a % of nesting female population (2009-2016)	% take risk to nesting population (annual)
Loggerhead	27	16.16	62	> 590	10.50 %	1.32 %
Green	29	17.36	94	> 10 000	0.94 %	0.12 %
Hawksbill	7	4.19	9	> 2 500	0.33 %	0.04 %
Leatherback	12	7.18	12	< 100	12.0 %	1.50 %
Olive Ridley	2	1.19	2	> 1000	0.2 %	0.02 %
Unidentified spp.	90	53.89	183	n/a	n/a	n/a %

** Records derived from; Fernandes et al., 2016a; Fernandes et al., 2015; Fernandes et al., 2014; Louro and Fernandes 2013; Videira et al., 2011; Pereira et al., 2010; Pereira et al., 2009; Louro et al., 2006.*

Spatial data: sea turtles' exposure to fishers

Mean annual SPUE for spear fishers increased over the study period (R-squared 0.95, F statistic = 47.48, p = 0.02; Fig. 4.6). While 79.1% of the variance found in the gillnet density could be explained by year, this relationship was not statistically significant (R-squared 0.79, F statistic = 7.57, p = 0.11). Neither was year a strong predictor of surface turtle density per kilometre (R-squared = 0.30, F statistic = 0.89, p = 0.44).

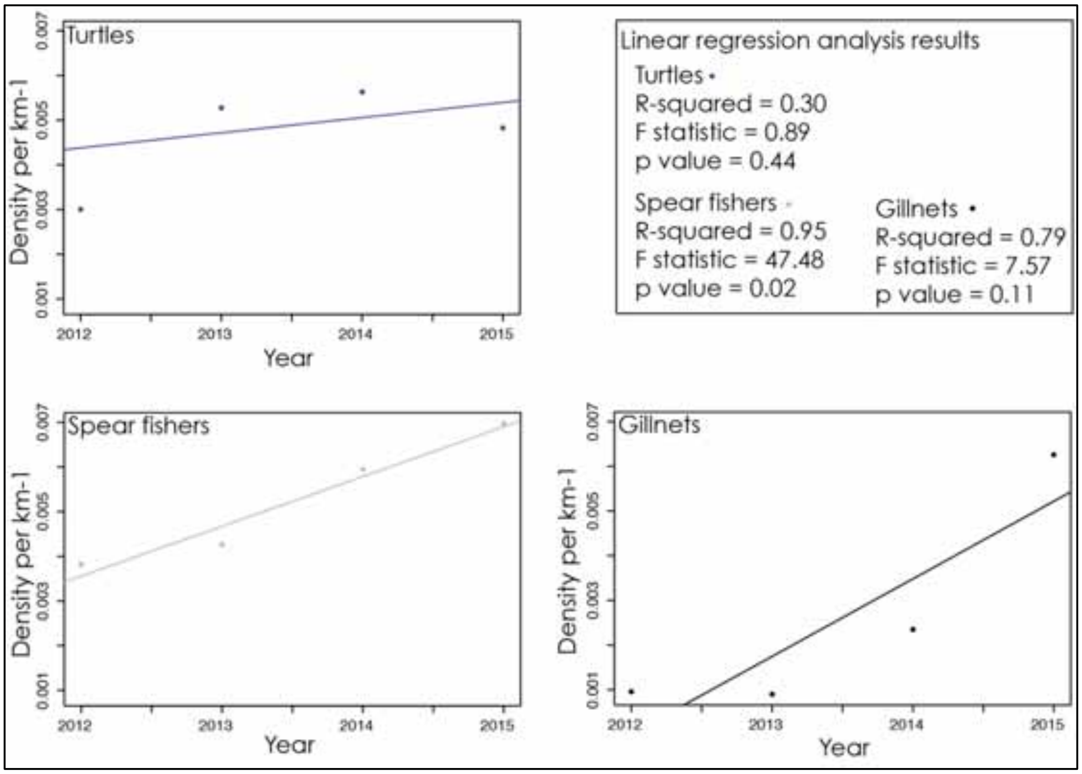


Fig. 4.6. Linear regression models fitted to density (number of events over total annual distance (km) covered) of turtles, gill nets and spear fishers encountered at the surface with year modelled as response variable.

Fisher SPUE was clustered in nearshore waters south of Tofo Bay (Fig. 4.7a). This distribution directly overlapped with turtle surface sighting data, so the high-risk area for illegal turtle take was concentrated on this region (Fig. 4.7b). Fishing camps were most commonly located south of Tofo Bay, in Tofinho, Backdoor and Praia de Rocha North beaches, which also coincided with fisher SPUE recorded from boat-based surveys (Fig. 4.8).

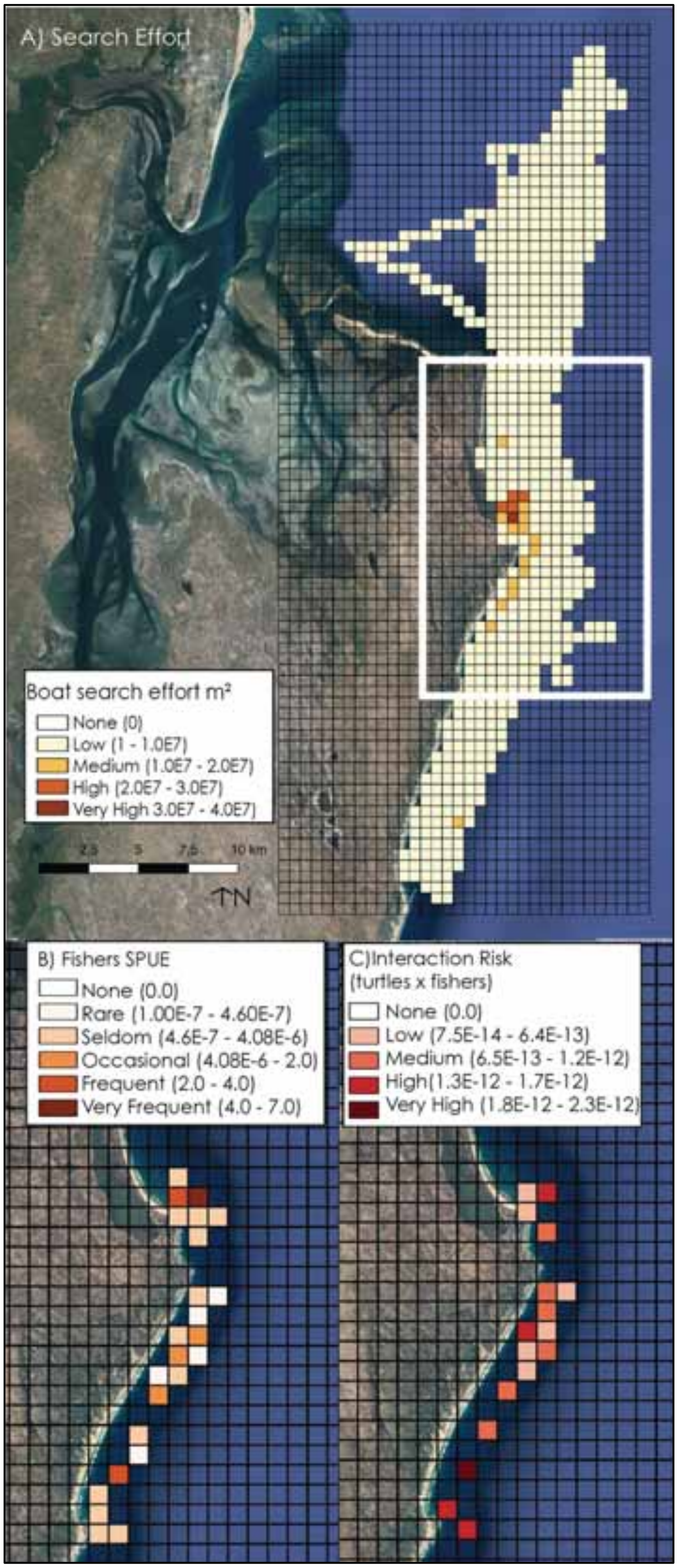
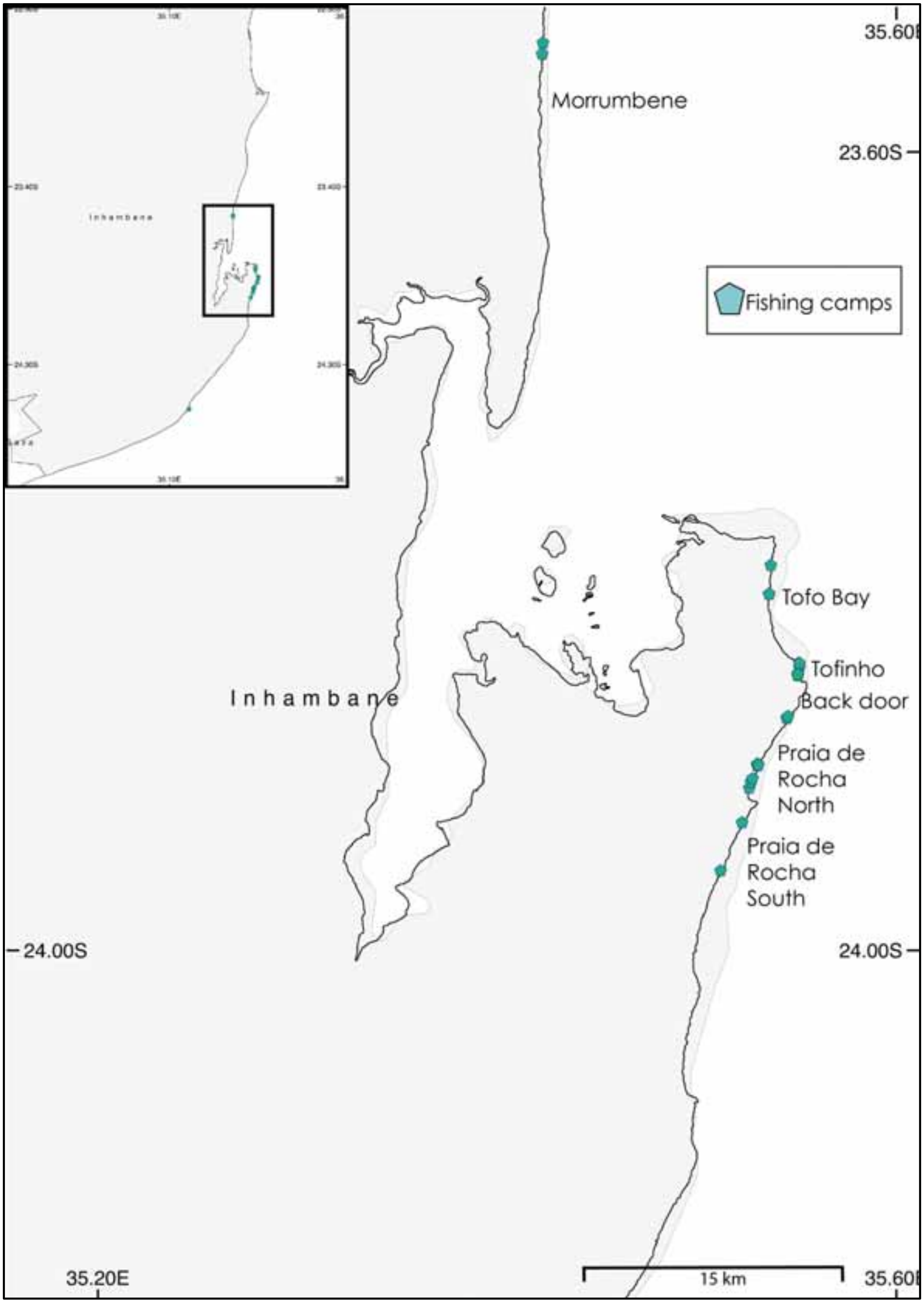


Fig. 4.7. a) Search effort by boat; b) spatial distribution of fishing threats (fishers SPUE, all gear types) and; c) and risk to turtles (fishers SPUE x turtles

SPUE) encountered at the surface between 2012 to 2015, Inhambane peninsula, Mozambique.



35.60E
Morrumbene
23.60S
Fishing camps
Tofo Bay
Tofinho
Back door
Inhambane
Praia de Rocha North
Praia de Rocha South
24.00S
24.00S
35.20E
15 km
35.60E

Fig. 4.8. Temporary or transient fishing camps of small scale fishers (blue pentagons) along the Inhambane peninsula documented on beach transects between 2010 – 2016.

Discussion

All five species of sea turtles using Mozambican waters are subjected to illegal take. Illegal take in Mozambique is not size or species specific, a trend similar to Madagascar (Walker and Roberts 2005). Our results demonstrate that likely impact of illegal take at the population level is not uniform across species. Given that my study reports on the first information on proportional abundance, this pattern (i.e. non-uniform impact of take across species), will need to be investigated further as more data become available. Green turtles were the most abundant species reported in our surveys of illegal take, both at the Tofo hotspot on the Inhambane peninsula and at a national scale. In comparison the majority of in-water sea turtle encounters on coastal coral reefs of Tofo were loggerhead turtles (Chapter 2 and Chapter 3). The abundance of green turtle remains detected from our beach surveys implies that green turtles may be more abundant overall, or are encountered more commonly by fishers in nearshore waters and habitats (e.g. estuary, seagrass meadows and mangroves) than found by recreational divers on the coral reefs.

The abundance of green turtles, and green turtle mortality is not a surprising given the relative proximity of Mozambique to Europa (~ 500 km east), the largest documented green turtle rookery in the SWIO (Lauret-Stepler et al., 2007). It seems probable that these animals originate from the Europa or one of the other three distinct genetic stocks/ RMU's recognised within the

SWIO region (Bourjea et al., 2015). Testing this using genetic-based research would be relatively straightforward.

Our results report high numbers of green turtle landings (relative to other species), yet only low level nesting (in the north, estimated as 50 breeding females annually on Vamizi Island; Garnier et al., 2012), which strongly suggests that the majority of turtles are likely to originate from other source populations elsewhere in SWIO. It may be that increased recruitment from such populations (e.g. increases in Grande Glorieuse (Lauret-Stepler et al., 2007), Europa (Lauret-Stepler et al., 2007) and stable populations in Mayotte (Bourjea et al., 2007) subsidise the turtle fishery in both Madagascar (Humber et al., 2011) and Mozambique, given that neither sustain significant green turtle nesting populations.

Unlike Madagascar, where the turtle fishery primarily impacts regional green populations and some hawksbill populations (Walker and Roberts 2005; Humber et al., 2011) Mozambique's turtle fishery also impacts loggerheads and leatherback turtles. Both loggerheads and leatherbacks populations are thought to be substantially smaller (based upon population estimates from nesting populations monitored within the SWIO) and thus their resilience to fishing pressures is likely to be lower. Our morphometric dataset showed that sub-adult and adult (min CCL of first time nesters > 84 cm; Nel et al., 2013) sized animals were being caught and killed. Although the loggerhead population is thought to be stable or showing signs of increases (Nel et al., 2013), the regional SWIO population is significantly smaller than that of greens (>590 nesting annually versus cf. 10 000) and illegal take of mature animals is likely to have a negative impact on recruitment for the species. This is also applicable to leatherback turtles (<100 nesting annually) even though mortality records were infrequent and relatively low in absolute terms.

Transect datasets

Beach transects were a useful tool to collect sea turtle mortality data and an indirect measure of likely to illegal take. Transects enabled the collection of morphometric data, geospatial information about each mortality event, along with contextual information about the environment and they were often able to provide details of the SSF techniques employed in capture (see Fig.4.9. for an example). However, a number of limitations were noted. While the beach transect methodology is low cost, low tech and can be easily taught (i.e. to citizen scientists or community monitors), the environmental conditions at our study site; such as tropical humid climate, very hot sand and steep vegetated dunes, meant that undertaking the transects is physically demanding and time consuming. In addition, logistics and access to remote coastal areas can be challenging (low density road netword, 4x4 vehicles in deep sand tracks only, if any). These factors strongly influenced the survey effort in our study and as a result spatial and temporal effort was variable across years.

Fig. 4.9. Temporary fishing camp between primary and secondary dune, on the northern beach of Praia de Rocha, Inhambane peninsula. Left inset shows size and structural detail of a fishing camp, with a shading rack and

elevated bench to keep catch sand-free whilst dissecting. Right inset is a close up of the fishing gear (two home-made spear guns, buoys, fins and rash vests for freediving and nylon rope gillnet) left inside camp.

Numerous factors influence the detection of mortality events and thus I am of the opinion that the beach transect results represent conservative estimates of illegal take. Due to the landscape the transects were conducted in – some of the steepest (up to 120 m) vegetated dunes in the world (Hatton 1995; Momade and Achimo, 2004) - it is possible that not all remains were detected. Older remains are bleached by the sun and do not contrast against sand colour well or become over grown by dune vegetation, or buried by dynamic wind/wave accretion and erosion processes typical of coastal dune systems, making it difficult to detect all turtle carapace remains. Another factor affecting detection is that the turtle remains break down over time, especially if left in full sun. The decomposition period of a carapace remains unknown. It would be useful to quantitatively document how long the remains persist before they are too degraded to detect. With this knowledge the maximum interval between mortality survey sessions could be determined and provide insight and greater confidence into the rates of illegal take.

The contextual information surrounding the remains of turtles found during the beach transects lead me to conclude that this mortality is caused by interaction with small scale fishers. It is possible that another explanation may exist to explain some of the mortality events reported here, however given that these carcasses were found in the sand dunes dragged up by fishers rather than washed up along the tide line, it suggests that the carcass was intended to be illegally used regardless of cause of death.

Some limitations arose from monitoring this clandestine activity. It was not possible to collect accurate morphometric data from all remains detected on transects, because the carapaces were often damaged (presumably from capture technique, particularly spearfishing), severed roughly (e.g. marginal scutes or nuchal notch cut away) or naturally broken apart from decomposition in the sun. Harpoon puncture marks were reported in a much lower proportion (7%), however this can be explained by two factors; 1) puncture marks were not a consistently reported data criterion in surveys and 2) fishers aim for the neck of the turtle and only if their shot is misaligned would a puncture mark to the carapace be evident. A large number of records from the "unidentified species" category could not be sized or identified to species level because the remains were too old (i.e. pile of sun bleached bones). Our morphometric dataset may underestimate carapace sizes (length and width) as fishers cut up turtle remains very roughly with machete. Interestingly, the majority of remains detected were carapace, plastron or bones. Encounters of a full carcass, skull, or flippers were very rare, which suggests that illegal use is prominent. The next chapter (5) supports this idea by presenting a description of how the turtle carcass is divided and distributed between fishers and their community (as indicated though interviews with fishers). Green turtles are the favoured sea turtle species around the world for meat consumption (Mancini et al., 2011b; Mancini and Koch 2009; IOSEA 2014; Humber et al., 2014) and the abundance of green turtle carapaces found suggest this may also hold true in Mozambique. Species differentiation by fishers occurs (based on interview results in Chapter 5), however fishers did not actively report selectively targeting green turtles based on a taste preference, and thus it may suggest that small scale fishers most frequently interact (intentionally or opportunistically) with green turtles, or that green turtles are most abundant.

Regional comparison

Given the spatial and temporal biases in survey effort, of our mortality dataset it is not suitable to comment on trends in seasonality of illegal take or evaluate yearly trends. Caution must be applied to prevent over extrapolation of these findings. Within the SWIO, quantitative surveys of illegal take or bycatch are rare (Kiszka 2012; Bourjea 2015). Community based monitors from 12 villages along a 60 km section of the coast in south-west Madagascar reported turtle landings in local SSF which lead to an estimate of 817 animals per 60 km of coastline in Toliara Province (Humber et al., 2011). Using total length of coastline in the province (1189 km) they estimate 10 000 – 16 000 as a conservative range for annual take (Humber et al., 2011).

The dataset presented here is positively biased (i.e. there were only records of illegal take from areas where I could access and survey) and does not address coastline paradox issues. Along the Inhambane peninsula, calculations based on linear distance rather than intricate coastline distances result in 1.36 turtles per km^{-1} over the entire duration (2009-2016) of the study. However, my results show that geographic occurrence of illegal take and temporal patterns are not homogeneous, at either the small scale (i.e. case study from surveys of the Inhambane peninsula) or within macro-scale (e.g. Inhambane Province), and certainly not at the national scale. In the subsequent chapter (5) I investigate the drivers and motives of illegal take in artisanal fishers, the result reinforces this heterogeneity, with evidence that individual behaviours, motives and drivers varied over small geographic scales (Chapter 5).

Motivations for taking sea turtles are varied, but often relate to either capturing the turtle to harvest its meat for consumption, or to use its carapace to make products (crafts and trinkets), both of which create the opportunity to generate income by selling either the animals meat, carapace or tortoise-shell products. The fundamental drivers of illegal take of wildlife are often simplified down to economically depressed, uneducated, and often local community members who have few other livelihood options (Knapp 2012). However, human behaviour is complex and varied, and illegal hunting has also been linked with desires as skill development, identity formation, opposition to authorities, boredom and thrill seeking (Forsyth and Marckese 1993, Shetler 2007, Knapp 2009). Insights from social aspects of SSF may help to explain the prevalence of intentional or opportunistic take and use of turtles and their products.

Discerning the cause of mortality

Mortality events detected from beach transects are unlikely to be caused by natural predation of nesting turtles. There is an absence of large predators and scavengers in the dune system, most terrestrial animals have been heavily hunted for bushmeat. The remains were consistently found in the dune swale, between the primary and secondary dune, the carapace cleanly cut away. Knife marks (clean, linear, angular, incisions) and predator bites (bite shaped marks, small puncture wounds, shredded flesh and debris scattered around the area) are readily differentiated. If predators were feeding or scavenging on turtle remains, evidence of the flippers and skulls would be visible, however during the entire 5 years of surveying no such evidence was detected. Whereas knife marks were visible on many remains.

I suspect beach transect results are more representative of targeted take rather than 'accidental capture' or intended take using gill nets, long lines or other SSF techniques. Some of the carapaces detected in the sand dunes had clear signs of puncture holes (n = 15), likely to be caused from a spear gun or harpoon. Interviews with spear fishers revealed the favoured place to aim the spear was in the neck of the turtle (Chapter 5), this explains why not all carapaces found had puncture holes present. Along the Inhambane peninsula I observed fishers adopting strategies to target particular species (typically more than one) and maximise their catches (by gear type, timing or placement of gillnets) (Pers. Obs.). Intentional gillnet or long line fishing in coastal waters (2.5 – 10 m) where nets are set perpendicular to natural rocky headlands, to capture marine megafauna species is prevalent (Pers. obs). Favoured strategies by fishers was to place nets perpendicular to submerged shoals or near marsh islands, because these 'landscape features' act as natural leads directing fish towards their nets, has also been reported in other places (North Carolina, McClellan and Read 2009). It seems plausible to suggest that in my study area, the majority of gillnet or long line fishing is conducted with the intention or preferential opportunism to capture sea turtles and other large marine megafauna species. Thus making it viable to argue that accidental take/bycatch from SSF does not occur in these fishing types in the study region. Two other factors also led me to conclude that the majority of records of illegal take detected from the surveys were from targeted hunting rather than non-selective fishing methods (e.g. gillnet, long-line, beach seine); 1) many of the remains detected have clear signs of puncture holes in the carapace and harpoons (sophisticated or home-made) are frequently found lying in the sand dunes nearby to turtle remains and 2) I have also detected evidence of empty carapaces being discarded overboard in shallow waters adjacent to the boat landing area before they can be detected once the boat has beached (Pers. Obs). Where fishers use a boat for their fishery technique (e.g. some gill netting, long-lining, purse seining, line and pole fishing), they have the opportunity to capture, slaughter and package turtle meat into discrete sacks (rice and grain sacks) whilst offshore, lowering their likelihood of being detected by the general public, tourists or enforcement authorities and thus reduce the risk of being penalised for illegal take of turtles. A more comprehensive investigation into illegal take (which include take from targeted, opportunistic and accidental) could yield significantly greater estimates of turtle mortality.

The rapid development of shark fisheries in Mozambique is of concern and a developing threat to turtle populations. Shark fishing for high value shark fin, has propelled the expansion of artisanal and illegal industrial scale fleets. These fisheries favour bottom set gillnets and long lines and which takes place in both inshore waters (artisanal scale) and offshore waters of the Mozambican exclusive economic zone (EEZ). The shark fishery is suspected to have catch large numbers of turtles (Pierce et al., 2008). Non-traditional shark fishing methods were introduced into Madagascar in the 1990's (Langley 2006) and a correlation between turtle and shark artisanal fisheries have also been reported, whereby such shark fishing methods provide a favourable and easier technique for hunting turtles than spear fishing (Humber et al., 2011). Pierce et al. (2008) reports of the ~ 85 km length of coastline between Morrumbene and Pomene (Inhambane to Maputo provinces of southern Mozambique) to have the highest concentrated artisanal shark fisheries of the south. Responses from small scale fishers (Chapter 5) also reveal a developing trend, whereby fishers were targeting sharks and turtles simultaneously, sharks for their high value fins and turtles for consumption in the fishing camps. Given that the artisanal shark fishery in Mozambique is larger than official estimates would suggest, and is probably still increasing in its size and sophistication (Pierce et al., 2008), it is likely to be an important threat to sea turtles in Mozambique.

Illegal take of nests and nesting females

During the study period, nesting events throughout Inhambane Province were low (32 nests in 5 years) and probability of nest success was also very low (28%). Extensive monitoring of nesting effort and confirming nest success was prevented by; 1) limited access to remote parts of the 90 km stretch of beach, and 2) a low awareness amongst coastal stakeholders to promptly report such events. Illegal harvesting of nests was common as evidenced by extensive digging, human footprints and broken fresh eggshells at nest sites. Interviews with fishers, (particularly in Dovela village) (Chapter 5) suggested that recent nesting turtle abundance is significantly less than pre-war nesting density (<1970's). Anecdotal evidence from long-term residents throughout Inhambane Province also report declines in nesting effort in the last decade/s (pers. obs). Given the absence of pre-war baseline monitoring of nesting activity or historical records, it is very difficult to confirm if a decline in the nesting density of sea turtles in Inhambane Province has occurred. Evidence suggests that the systematic collection of eggs and harvest of nesting females could justify low levels of nesting activity reported through this study. Similar declines in nesting densities have also been reported on mainland Madagascar (Rakotonirina and Cooke 1994; Walker and Roberts 2005; Humber et al., 2016). Another possible factor influencing turtle nesting is the increase of coastal development in the province in the past decade and the increase of artificial lighting and light spill areas which now deter nesting females that may have previously favoured nest sites along these beaches (Salmon 2003). Nesting effort remains low or declining in areas not affected by coastal development, suggesting other factors may be responsible for these changes.

Literature Review

Data on sea turtle mortality does not exist for the central provinces (Sofala and Zambezia), and reporting in both northern provinces (Nampula and Cabo Delgado) is infrequent and spatially limited (Louro et al., 2006; Fernandes et al., 2016). Reporting of mortality events was limited from offshore islands and these areas are suspected to be underreported and potentially high risk areas for turtles to interact with SSF or illegal take hotspots. When viewed on a national scale (using all data sources) the impact of illegal take on the Inhambane peninsula appears high, however survey effort was focused on this area, so I am unable to confirm whether sea turtle mortality is high here, or whether it appears inflated due to lack of survey effort elsewhere. Outside of the survey area within Inhambane Province, I relied on accounts from the literature. These reports are either reported by authors of the national status reports (JL Williams included), or project partners, and sometimes the general public. Many of these accounts did not identify the carapace/carcass to species level and it is only in some instances that photos were supplied enabling species identifications to be confirmed and reported. Regardless of method (beach transects or literature review) similar percentages (49% transects vs 54% literature) of mortality events were not identified to species level. However, given the fact that there is a limited capacity for outreach programs and public engagement (to report such events), these cases are likely to be freshly caught animals, whole carcasses washed up or freshly cut carapaces (prominent, easily detectible in busy or tourist areas) and therefore could have easily been identified to species level with improved stakeholder engagement and training. It is not possible to standardise records reported in the literature for search effort, given the opportunistic reporting of such events and thus, the positively biased dataset.

Spatial data

A direct overlap between turtles and SSF occurs in my study area. These results suggest there is a high risk to resident animals who occupy small home range areas for long periods of time and that such behaviour may put them at increased risk of being locally depleted from the area. However, SSF may also catch migratory foraging animals (i.e. wandering foragers e.g. juvenile loggerheads or leatherback), new recruits to developmental foraging areas (juvenile green turtles) and migratory animals that seasonally live in or seasonally use the area (e.g. residential areas for animals that make shuttling migrations from feeding to breeding grounds). Evidence from our photo-ID program supports some of these ideas (Chapter 3). Photo-ID provides robust evidence that the coastal waters of Inhambane Province are used by juvenile green turtles as residential developmental foraging grounds. McClellan and Read (2009) found that these are the preferred habitats of green turtles and artisanal gill net fishers in North Carolina, USA. This also applies in Mozambique. Where fishing intensity is high, turtles are exposed to and may interact with multiple fishing gears within their small home range (McClellan and Read 2009). Sub-adult and adult green turtles identified though photo-ID have shown shorter periods of occupancy in the Tofo area. While most adult greens appear to be transient to the area, some are detected multiple times, suggesting temporary or seasonal residency. The majority of loggerhead turtles identified were not sighted more than once, suggesting a transient/ migratory behaviour. Thus SSF captures of turtles in this area not only impact multiple species, they also impact both resident and transient animals, from a variety of size/age classes. Further details on both spatio-temporal dynamics of the turtles and SSF within our study area and Mozambican coastal waters are urgently needed.

Although direct spatial overlap between SSF and turtles occurred in our study area, this interaction does not imply mortality, and a number of factors need to be considered when discussing interaction or risk. The 'Risk Factor' of turtles becoming entangled or capture from artisanal fishing is unlikely to be constant or static. Alertness and cautious surfacing behaviour in green turtles has been reported on several accounts (Balazs et al., 1987; Renaud et al., 1995, Seminoff et al.2002; McClellan and Read 2009), suggesting that green turtles may alter their behaviour to avoid human activity. This avoidance behaviour is likely to be learned after repeat encounters suggesting that new or young turtles with less interaction experience may be at high risk and more susceptible to capture. In addition, the specific risk posed by different types of fishing gears resulting in entanglement or capture of turtles is likely to vary. Thus, accounting for the variability and complexity of how individual behaviours of fishers influence the 'impact' of their fishing activities will be important to understand before accurate estimates of interaction, catch and mortality can be made.

Our spatial dataset demonstrated the density of fishing effort increased during the study period, which coincided with reports from the literature that SSF in Mozambique, and in particular use of gillnets, is increasing with more than 43 000 nets are thought to be in use (IFAD 2011; IDPPE 2013; MIPE 2013). Difficulties in data collection and severe underreporting of SSF catches have been recognised and documented in Mozambique and throughout the SWIO region (Jacquet et al., 2010; Gillett 1995). Overall the artisanal fishing production levels have increased over three fold between 2005 and 2012 (Pereira et al., 2014b). Illegal take through use of non-selective fishing gear cannot occur without spatial and temporal overlap between turtles and gear (McClellan and Read 2009) and thus, increases in use of such gear along the Mozambican coastline is likely to increase the probability of turtle encounters and capture. Increased rates of entanglement of turtles in SSF gear is a serious concern given, that turtles can drown during forced submergences in 10 minutes or less (Sasso and Epperly 2006).

Data on the number of SSF related sea turtle mortalities are likely to be severely underestimates given the clandestine and illegal nature of the activity. Given this illegality, fishers are reluctant to speak about illegal take or report incidents of bycatch or hunting. The true impacts to turtle populations are likely to be delayed, subject to decade time lags, and may not yet be realised given the conservative life history of turtles (Humber et al., 2011). Our data indicate that illegal take affects adult and large juvenile life stages along the Inhambane peninsula. These life stages are known to have relatively large effects on population dynamics (Crouse 1999; Heppell et al., 1999; Donlan et al., 2010). It seems feasible to suggest that illegal take from SSF in Mozambique could be undermining conservation efforts throughout other parts of the SWIO. This concept has also been postulated for the Malagasy artisanal turtle fishery (Mortimer et al., 2007; Humber et al., 2016). Collectively the Mozambican and Madagascan SSF turtle fisheries are likely to be a serious threat to sea turtle populations of the region. Further work to quantify the scale and impact of SSF's in these areas and improve management strategies is required.

Managing illegal take

Management efforts to understand, prevent and/or reduce illegal take of turtles throughout the SWIO are limited. Managers have long reported that efforts to manage illegal take are severely hindered by a deficit in targeted research and monitoring (IUCN 1996; Mortimer 2002; Okemwa et al., 2005;

Kimakwa et al., 2008; Humber et al., 2014 and also reported in Chapter 6). In addition, management actions to address illegal take are sometimes superseded because managers are forced to make a trade-off between the severity of illegal take relative to other threats. Managers are forced to consider how addressing illegal take (or the scale and cost of activities required to improve compliance programs) will help achieve overall conservation goals (Sheil 2001; Kahler and Gore 2012). Compliance and enforcement actions are hampered by; 1) lack of spatially explicit information and 2) inadequate information about local stakeholder perceptions (Kahler and Gore 2012; Treves et al., 2006; Chapter 6). Identifying spatial distribution is paramount (e.g. the extent and location of illegal activities and the values being targeted), to ensure limited enforcement resources are appropriately applied to hotspot areas (Brown 2004; Knapp et al., 2010; Treves et al., 2006; Kahler and Gore 2012). Additionally, an understanding of stakeholder motivations and attitudes has the potential to increase compliance rates through targeting enforcement actions to key stakeholder groups (Sánchez-Mercado et al., 2008). Alternative strategies focussing on the grass-roots level by building capacity and awareness in local communities to sustainably manage their own use of marine resources may overcome some of the limitations in traditional top down management approaches. Ideally a combination of both approaches is required.

Management/ conservation solutions

Community based monitoring (CBM) techniques have been documented to be useful to access remote, small scale fisheries within Mozambique (Garnier et al., 2012) and the SWIO (Humber et al., 2016; 2015 and 2011). On Vamizi Island, a northern Mozambique community-based monitoring and management of sea turtles and other natural resources has been very effective and catalysed the creation of a community-led marine sanctuary (Garnier et al., 2012). CBM may also facilitate improved stakeholder relations, community capacity and rates of participation and buy-in for local conservation management regimes (Andrianandrasana et al., 2005; Evely et al., 2011; Garnier et al., 2012; Humber et al., 2016). Adopting CBM to monitor SSF and illegal take of turtles along more of Mozambique's coast would likely lead to improved conservation and management of turtles and trigger spill-over effects for other marine megafauna (e.g. dugongs, elasmobranchs).

Conclusion

All five sea turtle species occurring in Mozambican waters are subject to illegal take. Opportunistic take of turtles may be a broader scale problem than targeted hunting. Our findings suggest that illegal use of sea turtles primarily for consumption, is prevalent throughout Inhambane Province and is likely to be widespread throughout the nation. The prevalence of illegal take and use appear to be strongly linked to large scale socio-economic drivers, such as food security and poverty. Increasing coastal populations and a heavy national reliance on fish protein (50% of nations protein consumption) could lead to sustained or increased rates of illegal take of turtles. The situation is complex (fisheries methods, motives and drivers all inter play) and a single solution is unlikely. Both top-down and bottom up approaches to the problem should be adopted. The implications of illegal take are likely to have negative impacts on local nesting turtle populations using Mozambican mainland beaches or offshore islands. More information is urgently needed, especially before national estimates of illegal take can be derived. There is potential concern on a SWIO scale, particularly if the estimated quantities of illegal take in Mozambique are considered cumulatively with Madagascar.

Chapter 4 Summary

- Illegal harvest of sea turtles along the Mozambican coastline has been routinely reported, but largely undocumented.
- To survey for evidence of illegal take of sea turtles I conducted beach transects between 2009-2016, within the sand dunes of Inhambane Province and a literature review for the country.
- During the entire study period, I detected 362 individual incidents of illegal take, impacting all five sea turtle species present in the country.
- Of these 362, in Tofo, a hotspot in Inhambane Province, I detected 195 remains of illegally taken sea turtles from 57 beach transect surveys, incorporating three species (*C. mydas* 32%, *C. caretta* 18%, *E. imbricata* 1%). Almost half of all remains (49%) could not be identified to species level. An additional 167 records of illegal take were collated from literature records.
- Records of illegal take were distributed along the entirety of the Mozambican coastline.
- There was high degree of overlap between SSF and sea turtle presence around the Tofo area.
- The areas of highest risk for sea turtles to interact with small scale fishers were those that were easily accessible to people, inshore (<4 km from coast), adjacent to coastal headlands, or close to reef systems.
- The density of spear fishers and gillnets in the Tofo area significantly increased over the study period.

Chapter 5

Drivers and motives for illegal take and use of sea turtles in southern Mozambique.

In Chapter 4, I documented the widespread occurrence of illegal take of sea turtles throughout Mozambique, which takes place year-round and is neither species nor size-specific. Although sea turtles are protected by national laws in Mozambique, compliance is low. Therefore, this chapter investigates the socio-economic and cultural factors that relate to the widespread nature of illegal take and use of sea turtles in southern Mozambique. To accomplish this, I interviewed small scale fishers in two case study sites to understand variations in fishing techniques and behaviours. Two publications are planned from this chapter, a short article focused on the tradition of turtle hunting and consumption at Dovela, which has already been published, and a full paper that is in preparation.

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Abstract

Illegal take of sea turtles is widespread throughout Mozambique. However, the extent, motives and drivers for take are not well understood. Here I describe the socio-economic setting, motives and drivers of two coastal small scale fisheries in southern Mozambique (Praia do Tofo and Dovela), and the interactions these types of fisheries have with sea turtles. Using data obtained from semi-structured interviews, I present information on traditional and cultural valuations of sea turtles in these communities. Based on fisher responses, illegal take of turtles within the study area occurs from both targeted hunting and opportunistic harvest. Cultural significance of sea turtle hunting (where the turtle is cut and offered in a traditional ceremony) was only documented at Dovela. The primary reason cited by respondents for illegal take was for meat consumption. Respondents indicated opportunistic egg harvesting occurred, however, most noted a recent decline in encounters with nesting turtles or nests. From the responses I suggest a linkage between overall community poverty levels, the lack of alternative livelihood opportunities, and illegal turtle take. Similarities in the drivers between bushmeat hunting and illegal take of turtles in Tofo and Dovela were evident. The majority of fishers were aware of the illegality of harvesting sea turtles but noted the risk of being apprehended by authorities was very low and not an effective deterrent. Most fishers had more than one motive for engaging in illegal take. The dynamics of illegal take of sea turtles is complex; related effort, motives and drivers can vary widely, even across small geographic areas. More research into these complexities is needed in order to improve understanding of the context and patterns of illegal take within and between communities where these activities persists. Only with improved understanding can conservation

interventions that are socially, economically and environmentally sustainable be negotiated.

Introduction

At the end of the civil war, Mozambique's government adopted a neoliberal agenda in return for international donor support from the International Monetary Fund (IMF) through a comprehensive structural-adjustment package known as the 'Economic Rehabilitation Program' (1997). The goal of the program was to assist the government in rebuilding the country with a focus on decentralising state power and encouraging privatisation (Lunstrum 1997). Many argued that such reform would (and did) place additional strains on marginal populations, pushing them to adopt or continue bushmeat hunting for survival or trade, despite conservation regulations against the practice (Lindsey et al., 2013; Lunstrum 1997; Lunstrum 2013; Masse 2016). The term 'bushmeat crisis' has been coined to describe the threat of overharvesting wildlife for food (Redmond et al., 2006; Cawthorn and Hoffman 2015) and it is now regarded as an established threat to native mammals across Africa (Fa et al., 2014; Lindsey and Bento 2012; Lindsey et al., 2013), especially in the Congo Basin and other parts of tropical Africa (Brown 2007; Cawthorn and Hoffman 2015). However, the bushmeat crisis is not only a threat to biodiversity but also to the livelihoods of those who directly depend on this meat as a source of sustenance or trade for financial means (Clapham and Van Waerebeek 2007; Milner-Gulland et al., 2003).

Given the illicit and covert nature of such activities, accurate quantification of bushmeat trade is extremely difficult (Solomon et al., 2007; Kahler et al., 2012; Lindsey et al., 2013). Some scholars argue that bushmeat contributes significantly to food security in many areas (Milner-Gulland et al. 2003;

Cawthorn and Hoffman 2015). Others, that the benefits of illegal hunting are unsustainable in the long run (Lindsey and Bento 2012), especially as there can be a great deal of waste involved if only a portion of an animal is used (Lindsey et al., 2013). Contemporary approaches suggest that such animals are worth more if incorporated into "non-consumptive" activities (e.g. ecotourism, ecosystem services, intrinsic value) (Lindsey et al., 2013). In Mozambique, the rate of annual bushmeat consumption has been estimated at 182,000–365,000 tonnes, with an economic value of US$365-730 million/year (Barnett 2000; Secretariat of the Convention on Biological Diversity 2011). This estimate of bushmeat consumption, and much of the research focused on bushmeat, overlook the involvement/interaction of marine species (cetacean, sea turtle, sirenians), focusing on terrestrial species instead.

Some scholars (e.g. Wilkie et al. 2005; Fa et al., 2014.) suggest that bushmeat often represents a local protein source that is not easily replaced. For example, there may be challenges (e.g. suitable domestic replacement, higher costs) in procuring alternative protein sources. However, there is little empirical evidence to support this argument (Brashares et al. 2004). The motives and drivers for bushmeat consumption are diverse and variable across geographic scales, cultures, and communities (Forsynth et al. 1998; Hart et al. 2013). Further, bushmeat hunting and/or consumption is not always undertaken for personal use by people facing extreme economic hardships (Wilkie et al. 2005). There is an increasing demand for bushmeat from urban markets, which has catalysed a booming trade (Milner-Gulland and Bennett 2003; Swamy and Pinedo-Vasquez 2014; Cawthorn and Hoffman 2015). Illegal consumption of wildlife remains a problem even in relatively prosperous countries (Brashares et al. 2004).

Within the savanna biomes of eastern and southern African regions, nine drivers for illegal hunting and bushmeat trade have been identified: 1) inadequate enforcement; 2) money making opportunities; 3) protein shortages; 4) poverty/lack of alternative livelihoods/ employment; 5) weak penal systems; 6) corrupt game scouts/ employees; 7) human influxes/population increase forcing people to seek alternative meats; 8) livestock being held as assets rather than consumed/lack of livestock; and 9) lack of non-consumptive benefits from wildlife (e.g. ecotourism) (Lindsey et al., 2013). All of the nine drivers are present in terrestrial Mozambican conservation areas, and they can be synergistic (Lindsey et al., 2013). For example, drivers of illegal harvesting are often exacerbated by inadequate wildlife protection laws, enforcement and political instability (Lindsey et al., 2013). The latter is particularly relevant in Mozambique, where sixteen years of civil war and conflict resulted in increased rates of bushmeat hunting and had a significant negative impact on biodiversity and conservation. Troops of both conflicting parties, FRELIMO (Front for Liberation of Mozambique) and RENAMO (Mozambique Resistance Movement) were stationed in wilderness/ conservation areas (e.g. Gorongosa National Park) for protracted periods of time, where they hunted wildlife for sustenance and trophies (Hatton et al., 2001; Lindsey and Bento 2012). Additional pressure on the fauna arose from the support troops from South African and Zimbabwean armed forces stationed in these areas, and large population increases of thousands of refugees and internally displaced peoples into and adjacent to wildlife areas (Lunstrum 2008; Lindsey and Bento 2012). Bushmeat hunting continued post-war and bushmeat trade was facilitated by improved security and an expansion of road and rail infrastructure networks, which increased the connectivity between wildlife source areas and commercial markets (Barnett 1998; Lindsey and Bento 2012).

Marine bushmeat

The term ‘marine bushmeat’ was coined to reflect the realization that illegal marine hunts (e.g. of cetaceans, sirenians, and sea turtles) can have shared characteristics or drivers with their terrestrial counterparts (Alfaro-Shigueto and Van Waerebeek 2001; Clapham and Van Waerebeek 2007; Van Waerebeek et al. 2015). Direct links between terrestrial and marine exploitation of wildlife have been made. For instance, there is some evidence that hunting for terrestrial mammals increases following declines in local fisheries (Brashares et al., 2004; Clapham and Van Waerebeek 2007). Thus, a decline in one can prompt increased uptake in another and although terrestrial hunting seems to either precede or coincide with increased exploitation of marine life, scarce research attention has been directed to this matter (Brashares et al., 2004; Clapham and Van Waerebeek 2007). In South America and West Africa, some market survey studies suggest that the sale and consumption of sea turtle and cetacean meat is common (Van Waerebeek et al., 1997, Van Waerebeek et al., 2000; Fretey 2001). Clapham and Van Waerebeek (2007) argue that the turtle bushmeat trade might in fact be the main anthropogenic threat to sea turtles. Such claims are difficult to validate however, due to jurisdictional complications that make marine bushmeat trade and practice difficult to delineate and track. In many developing countries, illegal trade in marine species often can “fall through bureaucratic cracks” because there can be governmental uncertainty, or international confusion about whether it should be placed under the jurisdiction of fisheries or wildlife management agencies (Clapham and Van Waerebeek 2007).

Small Scale Fisheries

Small scale fisheries (SSF) usually operate in near-shore coastal habitats, and in many areas of the sub-tropical and tropical climatic zones these same near-shore coastal habitats are important for sea turtles (Gilman et al., 2009; Alfaro-Shigueto et al., 2010; Casale and Heppell 2016). Small scale fisheries are widespread throughout nearshore habitats (UNEP 2001) and easily accessible coastal waters, and high rates of bycatch or incidental capture of sea turtles, cetaceans, sharks and rays have routinely been documented (Koch et al., 2006, Soykan et al., 2008, Mancini et al., 2011). SSF contribute 91% of the total marine fisheries catch within Mozambique (IFAD 2011). Over 280 000 people depend directly on artisanal fishing with another 90 000 dependent on collecting and diving (Menzes et al., 2011). The number of people and boats engaged in artisanal fisheries in Mozambique is increasing annually although productivity is declining (IFAD 2011). In my previous chapter (Chapter 4) I documented nearshore coastal habitat use by sea turtles and the high rate of illegal take. Although some research has been undertaken on Mozambican SSFs, in terms of examining the resilience of fishing communities, social thresholds and adaption to change in the area (Blythe et al., 2013; Blythe 2014; Blythe et al., 2014), the impacts of Mozambican SSFs on the local environment and species is poorly understood.

Globally, little is known about the specific factors that motivate fishers to undertake illegal fishing behaviours (Koch et al., 2006; Moore et al., 2010; Mancini et al., 2011a, 2011b;). Within the Western Indian Ocean (WIO) region, motives for turtle fishing have been studied in Madagascar and Kenya (Okemwa 2004; Walker and Roberts 2005; Humber et al 2011). While there is evidence of widespread illegal take of sea turtles in Mozambique (Chapter 4), there is little information available on the details of the fisheries, the socio-economic contexts that impact and influence fishers, their motivations for engaging in illegal fisheries, or the relative importance of fishing in terms of household livelihoods. Further, few efforts have been made to document local traditions associated with turtle fishing or consumption. Greater attention on the social influences on, and aspects of, illegal take is required.

This study addresses drivers and motives for illegal take and use of sea turtles in southern Mozambique, and considers the possible scale of the problem within the greater context of the bushmeat crisis in Africa (Lindsey and Bento 2012). Using data obtained from semi-structured interviews, I describe the socio-economic setting, motives and drivers of two coastal small scale fisheries in Southern Mozambique (Praia do Tofo and Dovela), and the interactions these types of fisheries have with sea turtles. For the purposes of this study, I define motives for illegal take as the factors or reasons that influence fishers or groups of fishers to engage in illicit behaviour such as hunting turtles. The following definition was used to identify probable drivers of illegal take and use of sea turtles; large-scale social, economic or political factors or processes, common to a province, country or region (Robards and Reeves 2011; Cawthorn and Hoffman 2015; Hancock et al., 2016).

Methods

Mozambique: socio-economic summary

Mozambique was occupied by the Portuguese from 1752 until 1975. Two years after independence was established, civil war broke out 1977 and lasted until 1992. Since 1994, the Republic of Mozambique has been a democracy. Mozambique is one of the poorest and “least developed” countries in the world, ranked 180/188 on the Human Development Index (HDI 2015). Despite having one of the fastest growing GDP's in the world since 2001, the country's GDP per capita, human development, measures of inequality, and average life expectancy are among the lowest in the world. Economic stability is declining within the country, and at the time of conducting these interviews 2013-2014, 1 US dollar (USD) was worth 24 Mozambican meticais (MZN), however 1 USD is currently (2016) 75 MZN.

Study site

The study was conducted at two coastal small scale fishery sites in southern Mozambique: Tofo, and Dovela (Fig. 5.1).

Tofo (-23.51 °S, 35.23 °E) is a small village, located close to the provincial capital of Inhambane and a small international airport. Tofo is connected with the national highway by a sealed road, and the area is relatively well-developed and dependent upon an active tourism industry. Tofo is one of the most popular scuba diving towns along the southern Mozambique coastline, thought to be the most popular diving region within Southern Africa after South Africa (Boshoff and Boshoff 2008). Diving tourists flock to Tofo for its year-round populations of marine megafauna (whale sharks *Rhincodon typus* and manta rays *Manta birostris* and *M. alfredi*) (Tibiriçá 2011; Pierce et al., 2010). The Inhambane peninsula can be divided into three major areas, Barra, Tofo, and Tofinho. Fishers from the Inhambane Peninsula come from several larger village zones (Bomba, Pembane, Nhamoa, Tofinho, Praia de Rocha). The local dialect of this area is Bitonga and people identify as Bitonga (Tsonga) (Rita-Ferreira 1959). Respondents from Tofo area belong to the Inhambane municipality, of which the 'City of

Inhambane' district was estimated to have a population of 66 887 in the 2007 census (INE 2010).

In contrast, Dovela (-24.43 °S, 35.25 °E) is a small village in the Inharrime district, located approximately 2 hours (by car) south of the Inhambane city. The village is only accessible via a 12 km sand track off the national highway. The nearest town is Inhacongo (20 km). Dovela has one primary school. It is also relatively unique in that there is a small luxury eco-tourism lodge nearby, and a coconut oil processing factory as well. Matimbe, a village north of Dovela, is even more remote, and can only be accessed by foot. Five kilometres to the south of Dovela is Chume village. Fishers from Dovela, Chume and Matimbe commonly move between the three areas depending on particular fishing preferences of the day or season. It is not uncommon for fishers to have multiple families-- one in each village. The local dialect of this area is M'Chope and the people identify as Chopi (Rita-Ferreira 1959). Dovela respondents belong to the greater populous of Inharrime district with 100 379 people (2007 census, INE 2010).

Illiteracy rates vary between districts, 19.8% (10.2% male, 27.9% female) of the total population in Inhambane district, and 41.0% (22.9% male, 52.8% female) in Inharrime district (INE 2010). Living standards are basic in both districts with 'mixed/casa misto' houses (39.3%) (houses made with a mix of durable materials e.g. zinc roofing sheets, concrete foundation, cement cinderblocks and natural materials i.e reed, thatched walls), and 'huts/ palhota' as second (38.9%) in Inhambane. Huts (primarily made from naturally sourced materials e.g. palm, reeds, grasses) are the most abundant house type in Inharrime (64.1% cf. mixed houses 24.9%) (INE 2010). Religion varies between districts with the highest proportion of people in

Inhambane identified as Catholic (33.2%). In Inharrime district those without religion (36.5%) or 'Zion/Siᾱo' (34.4%) were most prevalent (INE 2010).

Fig. 5.1. Fishers (total n =27) from two coastal villages, Tofo (n = 17) and Dovela (n = 10), within Inhambane Province (displayed as grey inset), southern Mozambique participated in semi-structured interviews.

Semi-structured interviews

Semi-structured interviews are a flexible interview technique where the interviewer decides in advance the interview subject and main questions to be discussed. The structure, order and detail is determined during the course of the interview, allowing the interviewer to ask further probing questions or vary the level of detail and depth of a particular subject (Mancini and Koch 2009). Semi-structured interviews were conducted with turtle fishers to document details and attitudes towards fishing, logistics of the turtle fishery, motives for fishing, and suggestions about local traditional and cultural significance of turtles (Table 5.1). Respondents were selected from two main coastal areas (Tofo/Barra/Tofinho n = 17; collected between April 2012 - October 2014) and (Dovela/Chume/Matimbe n = 10; collected between May 2015 - November 2015). Study sites are henceforth referred to as Tofo and Dovela (Fig. 5.1). The questionnaire had seven major themes; 1) household economy, 2) description of the (non-turtle) fishery, 3) interactions with turtles, 4) rates of illegal take, 5) enforcement, 6) traditions and culture and 7) perception of changes to fisheries (including sea turtle fishery). Interviews were designed to solicit as much quantitative information as possible in order to describe the small scale fisheries and their interaction with sea turtles. Interviews were conducted with assistance from local translators. Depending on the preferred language of the respondent, the interviews were conducted in Portuguese and/or one of the two local dialects: Bitonga or M'Chope. The interviewer had a questionnaire consisting of 57 questions to guide the discussion and an additional eight questions about respondent demographic information (sex, birth place, age, schooling level, number of family members to support, community/village) (see supplementary material for questionnaire; key themes are presented in Table 5.1). Interviews took between 20 and 50 minutes to conduct. The questionnaire was adapted and modified from similar work conducted with fishers in Mexico by Mancini et al. (2011). All respondents participated on a voluntary basis and were allowed to skip any questions they did not wish to answer. They could also terminate the interview session at any time. Respondent identities remain confidential, and data is presented using alphanumeric identifiers (D1-10 for Dovela respondents and T1-17 for Tofo).

Analysis

Open-ended questions were analysed using qualitative data analysis software nVivo 11. Common themes and patterns in responses were summarized and tallied for each topic/section, and alternative responses were noted (Patton 1990). Responses were also evaluated to see if location had an influence on the dynamics of the turtle fishery or fishers' behaviours. Sample sizes varied per area (either Tofo or Dovela); to show this variation I report specific sample sizes where applicable. Given the voluntary nature of the interviews, sample size per question varied because respondents declined or provided responses that were inadequate for analysis to some questions. Where possible, quantitative results are presented; however, many respondents had difficulty quantifying their responses. As response rates varied per question, sample size varies and thus n_r is used to present the specific response rate of each question. Collating common themes revealed in the interviews, I identified motives and drivers for fishers to engage in illegal take of sea turtles. I defined motives as factors that influence individual fishers to engage in illegal take of sea turtles. I defined drivers as large-scale factors or process which influence coastal communities and their livelihood options.

Table 5.1. Summary of key themes and subthemes asked of small-scale fisher respondents, using semi-structured interviews in Tofo and Dovela, in southern Mozambique.

Key themes	**Subthemes**
Household economy	Economic activities, income from each activity, traditional family activities, years spent fishing, motives for fishing, availability and participation in non-fishing livelihoods
Description of the (non-turtle) fishery	Target species, fishing techniques, fishing areas, group and solo activities, source of fishing equipment, frequency of fishing, typical catch species, importance of catch to family diet, and sale of catch (mean revenues resulting)
Interactions with turtles	Reported frequency of catching turtles, methods for catching, frequency of encountering nesting turtles, ability to differentiate between sea turtle species, sale and price of turtle meat, effort to catch turtles, motives for catching
Rates of illegal take	Reported quantity caught per day/week/year, duration (years) participating in turtle fishery, egg harvesting and consumption rates, species and size preferences,
Enforcement	Reported knowledge of sea turtle-related laws, experiences of encountering and/or evading enforcement officers and officials, and knowledge of penalties,
Traditions and culture	Intention/s behind meat and egg consumption, traditional customs for hunting, traditional fishing areas, and traditional fisheries closures,

Perception of changes to fisheries (including sea turtle fishery)	Comments on fisheries catch rates, turtle catch rates, quantities of fishers, environmental changes, motives to stop fishing, fisher concerns about the future, and availability of alternative (non-fishing) employment.

Results

Fishers demographics

Respondents choice to answer questions was variable. To show this variability per question n_r is used to show the response rate for a particular question. Respondents in Dovela were older than Tofo, on average, with a median age of 49, compared to 27 years in Tofo. Dovela's respondents reported having more than double the fishing experience (21 years) as respondents from Tofo (8 years, n_r = 6), on average (Table 5.2). Fishing was a traditional family activity for 60% of the Dovela respondents (n_r = 6), compared with 24% (n_r = 4) of the Tofo respondents. Average education levels varied between fishing communities. The majority of the Dovela respondents (90%, n_r = 9) reported having attended primary school (until grade 4), while only one quarter (24%, n_r = 4) of the Tofo respondents had attended school (until grade 5) (Table 5.2). A higher proportion of the respondents from Tofo were full-time fishers (55%, n_r = 9) than in Dovela (30%, n_r = 7). Most of the Dovela respondents stated that they split their time between fishing and subsistence farming (small vegetable gardens known locally as machambas). Few respondents in either community had alternative livelihood options (Table 5.2). I defined alternative livelihoods as any formal or non-formal employment opportunities the generated income excluding small scale fishing or farming (machambas).

Table 5.2. Summary of respondent demographics in Tofo and Dovela. Response rate per question is shown as n_r. Response rate per category displayed in brackets.

	Tofo (n_t = 17)	**Dovela (n_t = 10)**
Median age	27 (range of reported ages: 19- 37)	49 (range of reported ages: 23 – 67)
Number of years of fishing experience	8 ± 2.6 years (median +SE) (range: 4 to 29 years of experience) n_r = 17	21 ± 5.4 years (median +SE) (range: 6 to 40 years of experience) n_r = 10
Fishing as Family livelihood tradition	24% n_r = 4	60% n_r = 6
Formal education	24% attended (average completed formal education level to grade 5) n_r = 4	90% attended (average completed formal education level to grade 4) n_r = 9
Livelihood diversity (fulltime fisher vs. part time)	55% full-time fishers 22% part-time fishers (carpentry training, hospitality) 22% retired fishers n_r = 9	30% full-time fishers (3) 70% part-time fishers either: - 50:50 farming and fishing (4) - ex-soldiers (2) - Driver (1) n_r = 10

Number of family members to support (including self)	2 (median) 2/6 fishers provided for themselves only. $n_r = 6$	9 (median) 3-14 (range of family sizes; number of members) $n_r = 9$

Target catches, sales and fishing methods

Tofo fishers

Tofo fishers targeted pelagic game fish (e.g. tuna, bonito, barracuda), benthic invertebrates (e.g. prawns, crayfish), cephalopods (e.g. octopus, squid) reef fish (e.g. groupers, parrot fish, moorish idols) and megafauna (e.g. turtle, rays, sharks). Shark fins were identified as being the most profitable item caught by local Tofo fishers (3 500 MZN kg^{-1}). Shark meat ranged from 50 – 150 MZN kg^{-1} and shark teeth sold at 60 MZN kg^{-1}. Ray meat was sold for 80 MZN kg^{-1} and turtle meat was sold at a similar price 80 – 100 MZN kg^{-1}. Tofo fishers sold some of their catch directly to lodges and restaurants, or directly to tourists. Catches were also sold in the local market at Tofo, in nearby village markets, and in the provincial capital city, Inhambane (20 minutes away by car). Reported fishing methods were diverse, but the majority of fishers self-identified as spear fishers (71%, n = 14). Other techniques used included line/pole fishing, gillnets and hand-set long lines. Fishers stated that they switched between gear types depending on target catch or weather/ocean conditions. Fishers in Tofo (100%, $n_r = 12$,) regularly fished as part of a team, however 3 of them (25%, $n_r = 12$) also stated that they also fished alone. The frequency of fishing activities was weather-dependent and variable. Most indicated that they fished every day (66%, n = 3), while some only fished on weekdays (33%, $n_r = 3$). All Tofo respondents reported having sold their catches ($n_r = 6$).

Dovela fishers

Dovela participants in the project reported targeting mostly reef fish (e.g. glassfish, groupers, goatfish, moray eel), intertidal molluscs, benthic invertebrates (e.g. crayfish), cephalopods (e.g. octopus), predatory pelagics (pompano, stinkers, rubberlip, Natal stump-nose) and limited types of megafauna (rays). Octopus and crayfish were stated as being the most profitable, fetching 150 MZN kg^{-1}. Their best quality fishes sold for 100 MZN kg^{-1} and the 'peixe pedra' (reef fish) for 80 MZN kg^{-1}. Respondents also discussed selling small fishes *"uma varra"* --threaded on a stick, for 50 MZN each. These are typically composed of two small pompano fish, three sergeant majors, or two or three surge wrasse, depending on size. Crayfish and octopus were often sold to middle men in the village, who would then sell them on the National Highway (EN1) at 200 MZN kg^{-1}. They felt there were limited opportunities for selling their catch directly to tourist consumers, given that only one lodge exists in the area. Line/Pole fishing was the most commonly used fishing technique among Dovela respondents (80%, n_r = 10), according to their answers. Additionally, spearfishing was a common technique employed by some (50%, n_r = 10). Primarily, respondents fished alone (66%, n_r = 9), but some fished in teams (33%, n_r = 10) in Dovela. Patterns of fishing activity (duration of trips and frequency) were more diverse in Dovela. For example, two respondents reported that during favourable fishing conditions, they would often sleep at the beach for 2-4 days per week. Others (n_r = 2) camped 3 weeks of every month and many (n_r = 6) made daily excursions when whenever the weather permitted. All Dovela fishers (n_r = 10) sold their catches.

Interactions with turtles

All respondents admitted to having encountered nesting turtles (Tofo, n_r = 3 cf. Dovela n_r = 7). More Tofo respondents (67% n_r = 10) admitted to having caught nesting turtles than Dovela respondents (33%, n_r = 6) (Fig. 5.2).

> "*At that time it was very easy to kill turtles because they were a species that was not afraid of people and it was very normal to find turtles sleeping and grab them for consuming within our community and nothing else/more*" respondent T4.

In Tofo, most respondents (85%, n_r = 14) caught foraging turtles in-water either intentionally or opportunistically.

> *"Yes. If we find the turtle, we take it out of the ocean and put it in the boat"*- respondent T17. Tofo respondents struggled to estimate quantities or rates of in-water capture (n_r = 3).
>
> "*Though I killed many in a day, I never was counting how many I had killed*" respondent T9.
>
> Frequency or prevalence of opportunistic hunting or retention of accidentally caught turtles occurred when fish catches were low/none.
>
> "*Yes. When a turtle gets caught on the line and then we pull it up and take it off the hook and release it. If we haven't caught any fish, then we will keep the turtle*"- respondent T15.

In contrast, none of the Dovela respondents reported having captured turtles in-water (n_r = 10). The reported catch rate of turtles also varied between locations. Dovela respondents reported occasionally catching turtles during the nesting season (October- March). All Tofo respondents said that catch rates discussed were in the past and that it was no longer possible to catch turtles in those quantities in Tofo anymore.

"*Even in a day you could catch 3 turtles but not in Tofo anymore*"- respondent T12. "*For a long time the turtles they were easy to see and now we don't see them anymore*"- respondent T16.

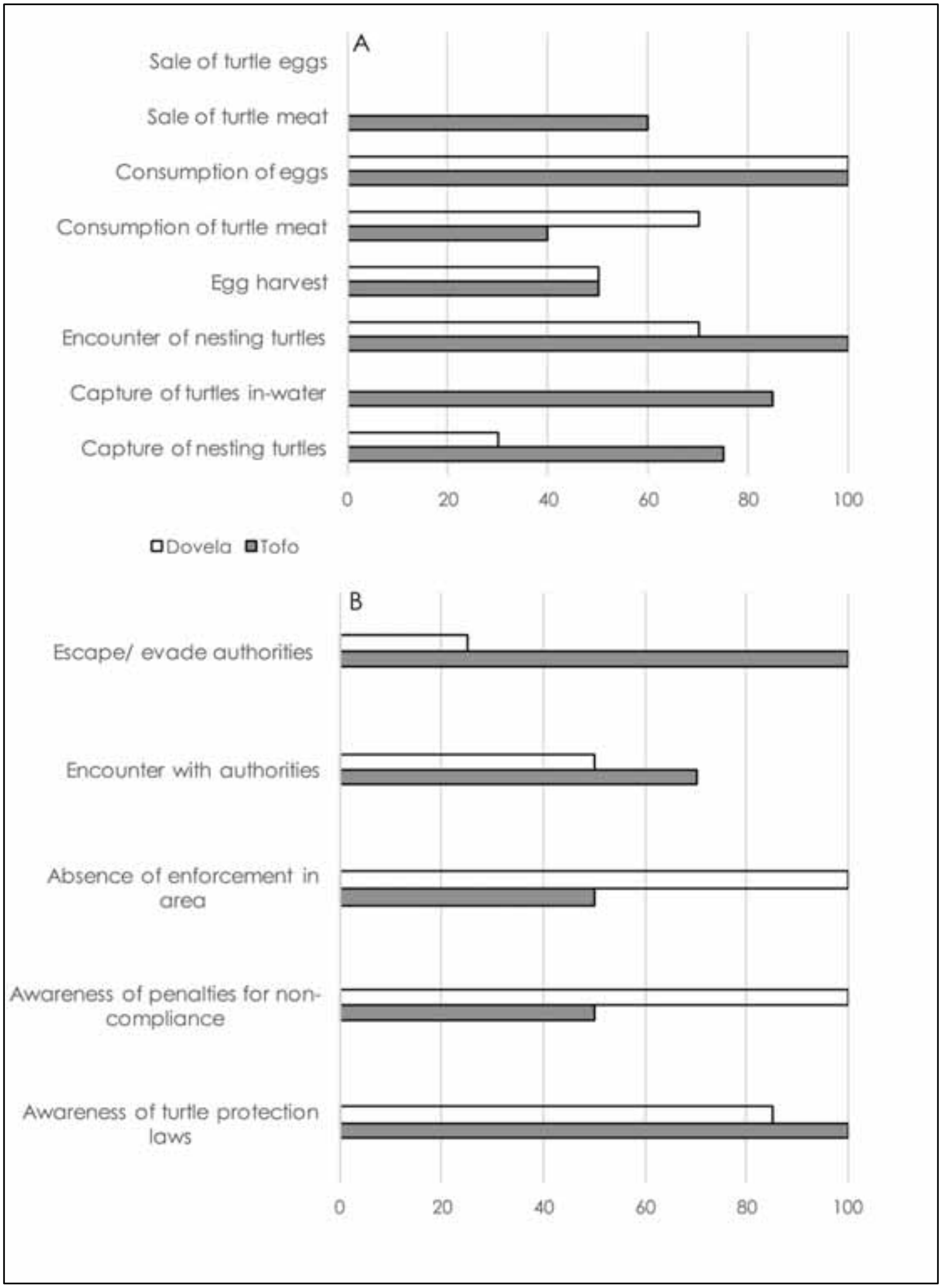

Fig. 5.2. A) Encounter, capture, consumption and sale rates (% responses per question per area) of nesting turtles, eggs and foraging turtles in-water. B) Percentage of respondents (Tofo or Dovela) with awareness of turtle laws, penalties for non-compliance and encounters with local authorities.

Reported consumption of turtle meat was slightly higher among respondents in Dovela than Tofo (63%, $n_r = 8$ cf. 50%, $n_r = 4$). However, in Dovela only one respondent had eaten turtle meat within the past two years, all other respondents ($n_r = 3$) had not consumed turtle meat since childhood.

> *"In the olden days, I ate turtle, my father was a leader and it was part of his tradition. It was still the colonialism time" Respondent D10.* In Dovela, turtle meat was not sold. Instead, respondents who had consumed turtle were given it through a hierarchy system (either by being part of family of the traditional chief, one of the fishers who caught the turtle, or one who helped to carry the carcass from the beach back to the village). "*No, I don't sell them. I eat them and I give the eggs. I never sell a turtle, they are a Jesus' present so we can't sell it, we have to eat the meat. It is the tradition; we can't sell them"- respondent D1.*

Most Tofo respondents sold their turtle meat to other villagers or communities (60%, $n_r = 5$) and some kept meat for consumption themselves or within their family (40%, $n_r = 5$) (Fig. 5.2A). "*We are catching for eating, to share with friends and half we sell*"- respondent T17. Occurrence of egg harvesting was the same between fishing communities (50%, $n_r = 4$ in each area). One quarter of respondents in Tofo had never encountered a sea turtle nest. An additional quarter of respondents had not raided a nest but seen others doing so around Tofo. In both communities ($n_r = 2$ in each area) the purpose of collecting eggs was only for consumption rather than sale.

Knowledge of laws and enforcement

Almost all of the respondent were aware of turtle protection laws (100%, n_r = 10 in Tofo; 88%, n_r = 10 in Dovela) (Fig 5.2.B). Consequences and penalties for breaking those laws were lesser known (50%, n_r = 4 in Tofo; 100%, n = 7 in Dovela). Respondents reported that enforcement in action was absent in Dovela and highly infrequent in Tofo (Tofo, 50%, n_r = 2; Dovela, 100%, n_r = 6). The local village chief was referred to as the only form of enforcement in Dovela. For instance, "*Well, there are fishes or sea animals that we are not allowed to catch: turtles, dolphins, mantas, whale sharks. The chief said so. The whale sharks, the dolphins and the whale shark's brother (bowmouth guitarfish) save people's life. The mantas, even if they don't save lives, we are not allowed to catch them. In fact, the chief told us that the mantas, the turtles and the dolphins are the forests of the sea*" -respondent D10.

Many of the Tofo respondents had previously been caught by authorities (67%, n_r = 3), for illegal fishing. While Dovela respondents noted a lack of enforcement or presence of authorities in their immediate area, 50% (n_r = 8) had encountered authorities in neighbouring fishing areas they frequented (Zavora, Zavala, Ligogo). Respondents in Tofo who had been caught by authorities also reported having evaded or escaped punishment/ enforcement (100%, n_r = 2). In Dovela most respondents did not report that they had participated in evasion of enforcement (75%, n_r = 8), however one respondent stated that he had been caught outside of Dovela, in the Ponta do Ouro Marine Partial Reserve, approximately 600 km south of Dovela.

Motives for illegal take

By categorising respondents answers, eleven motives or circumstances leading to the illegal take of sea turtles in these two areas were evident: 1) no successful fishing catches, 2) household meat consumption, 3) household need for income/cash, 4) lack of authority/enforcement presence, 5) Village chief's request for turtle products, 6) low likelihood of penalties being enforced, 7) demand for carapaces, 8) retention of accidental or incidental bycatch, 9) lack of alternative employment, 10) family tradition(i.e. intergenerational livelihood activity), and 11) community cultural/ceremonial traditions. Most respondent fishers (from both areas) cited multiple motives for participating in illicit turtle fishing activities. Regardless of community, the most frequent motive offered for the illegal take of sea turtles was household meat consumption needs (8/27: subject frequency of occurrence), followed by the need to sell meat for income (5/27), and the lack of alternative employment (5/27). Accidental or incidental bycatch (4/27) was also reported, although strictly not a motivation rather a circumstance but respondents did report keeping turtles caught this way. The motives for illegal take could broadly be sorted into five thematic groups (Fig. 5.3). Key examples of motive categories are illustrated with quotes from respondents presented in Table 5.3.

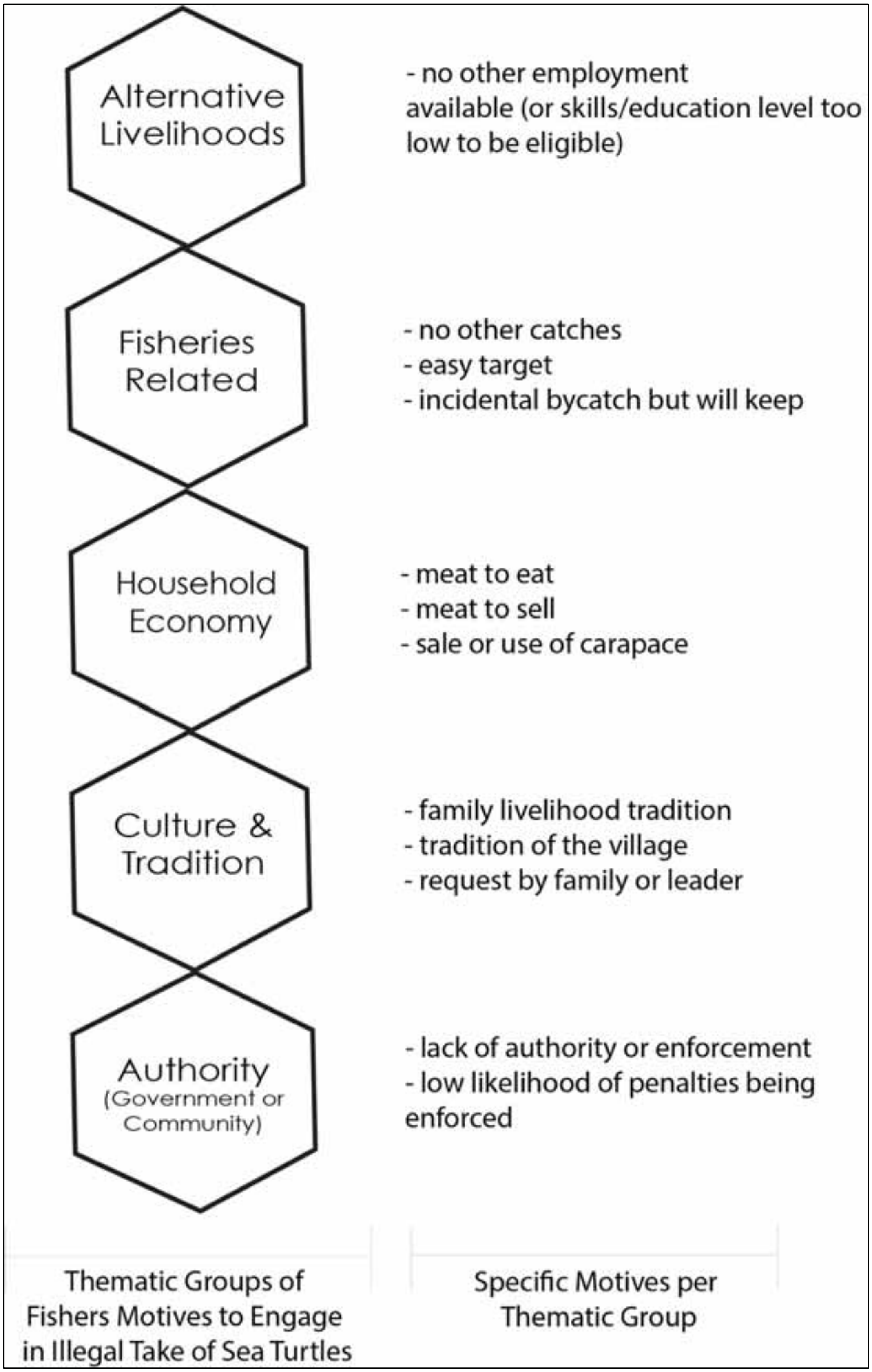
Alternative Livelihoods
- no other employment available (or skills/education level too low to be eligible)
Fisheries Related
- no other catches
- easy target
- incidental bycatch but will keep
Household Economy
- meat to eat
- meat to sell
- sale or use of carapace
Culture & Tradition
- family livelihood tradition
- tradition of the village
- request by family or leader
Authority (Government or Community)
- lack of authority or enforcement
- low likelihood of penalties being enforced
Thematic Groups of Fishers Motives to Engage in Illegal Take of Sea Turtles
Specific Motives per Thematic Group

Fig. 5.3. General representation of motives and circumstances of respondents from two coastal villages (Dovela and Tofo), southern Mozambique to engage in illegal take of sea turtles.

Table 5.3. Quotes from Tofo and Dovela respondents to illustrate motives for illegal take.

Motives	Example quote from respondents
No other fish caught	"*If we haven't caught any fish then we will keep the turtle"- T15.* *"When I started there were lots of big fish to catch, then one year later there were not that many fish to catch so I started to catch for turtles"- T12.*
Household meat consumption	"*We are not feeling well to kill these kind of animals, but we are feeling hungry in our house and the kids they want to go to school so we have to give them money*"- T16.
Household need for income/ cash	"*Because I had nothing to eat. Thanks to this activity, I can buy some rice*"- D3. "*I became a fisher to buy some soap*"- D8.
Lack of authority	"*No, I have never seen any inspection around here*." – D8.
Village chiefs request	"*There was a rule that when you enter a new place, you have to give a present to the local chiefs before you are allowed to fish there. To meet the chief you have to catch a turtle first and leave it with him, then you are allowed to fish in that area*" – T12.
Low likelihood of penalties	"*Yes I have known for a long time that it was always prohibited but because I am without alternatives I have to take the risk*" – T5.
Demand for carapaces	"*We actually sell the turtles shell*"- T16 *"I would sell the meat to the local people and try to sell the shell to whoever would like it"- T17.*

Retention of incidental catch	“*If we haven’t caught any fish then we will keep the turtle*” – T15.
Lack of alternative livelihoods	“*It is a craft that I have come back to after being integrated back from the troops and having nothing to do*”- respondent T3. “*Yes, fishing because I don’t have another job. But if I could find another job I would leave fishing and it would be good*”- T11. “*We don’t steal so it’s better to go to the ocean. Anything we find to eat or sell is better than having to steal. We don’t want to steal and we don’t have a job, so we go to the ocean to help make our life better*” - T14
Family or community traditions	“*Spearfishing is a family tradition, but catching turtles is not.*” – T12 “*In the olden days, I ate turtle, my father was a leader and it was part of his tradition. It was still the colonialism time*” – D10. “*Today, there is no more tradition so there are less turtles coming to nest. Today, no one knows how to pray properly, the content has been forgotten. The chief used to practice his tradition, he was speaking to his dead family members but I don’t know what he was telling them” – D9* *“Today, there are many turtles in the water but they don’t get out of the sea because they are not ‘called' anymore. There is no more tradition to ask them to get out of the water” –D7.*

Drivers of illegal take

Applying a thematic coding for responses, I identified six large-scale factors driving illegal take of turtles within Tofo and Dovela in southern Mozambique: 1) declines in local marine resources, such as fish; 2) food security; 3) poverty; 4) enforcement and compliance; 5) lack of alternative livelihoods; and 6) culture and religion (Fig. 5.4). Driving forces that influenced respondents to hunt and use sea turtles reflected three main themes- 1) socio-cultural, 2) economic or 3) environmental. Many of the motives for illegal take were also applicable at a larger scale as drivers (e.g. declining marine resources).

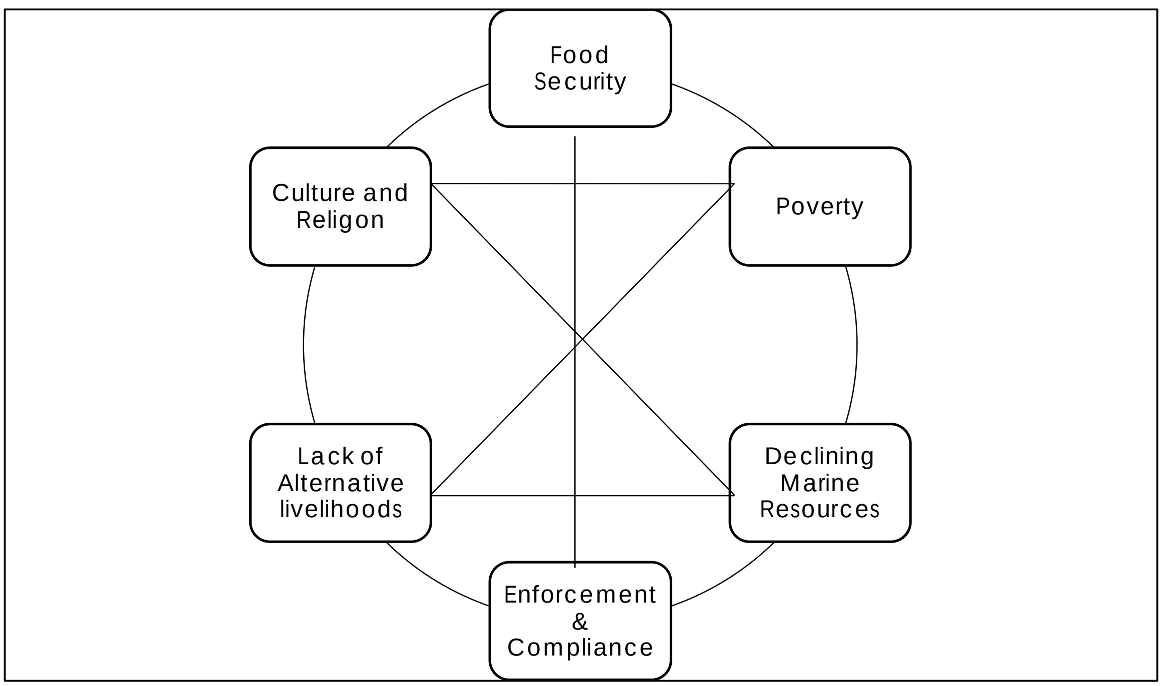

Fig 5.4. Drivers for the illegal take of sea turtles in Tofo and Dovela, southern Mozambique.

Perceptions of environmental change

Respondents in both areas perceived the fishing and/or the environment to have changed. Tofo respondents most frequently (*cf*. Dovela respondents) referred to changes in turtle numbers (declines in both nesting females, nests and foraging animals).

> "*Well it depends, it's a little bit difficult in Tofo, because it's a little bit degraded and it became more forbidden here. Well the rule is like, since we are born we all know that we can't kill turtle. Even in a day you could catch 3 turtles but not in Tofo anymore*"- T12.

Tofo respondents expressed conflict between fishing, as their main livelihood, and increasing tourism levels that are reliant on encountering marine megafauna;

> "*the customers (*tourists*) were coming here more to see the sharks, whales, turtles and rays but now we are doing the wrong things because we don't have any jobs*" – T16.

In addition, Tofo respondents attributed increasing tourism as part of the cause of the increasing difficulty to actively hunt for turtles in public

> "*In Vilanculos and Tofo, fishing is banned - from the tourism and it's a high chance to get caught*" –T12.

In Dovela, fishers referenced local changes to their environment in the context of flux in fish numbers, fishing seasons, weather patterns (changes to rainfall) and lack of traditional harvest regimes or seasonal fisheries closures (i.e. intertidal harvest). Seasonal influences to fishing success were noted;

> "*I see a big difference between winter and summer. In summer, fishing is much harder*"- D7.

Declining quotas and sizes of catches were referenced by several respondents from Dovela;

> "*There is much less fish and crayfish than before. Today, we catch almost nothing in our nets or with the hooks. Before, we did not need to go behind the reef to catch something. We came in the water in front of the reef and we could see fishes, crayfish's antennas in a very short time*. (Interviewer: Do you have any idea of the reason why it has decreased?) *Because of the lack of tradition, nobody knows the right words to say in the prayers so there is no more accurate tradition. Also maybe because of the difference in the temperatures"- D9.*

Concerns of unsustainable harvest practices and a lack of control (either community regulated or governmental) were expressed by respondents from Dovela;

> *"I have a lot of concerns for the future. Especially the fact to kill small fishes and not let them grow, the same goes for crayfish. Also, the hooks are smaller and smaller... the same works with the nets, their "holes" are smaller and smaller. Our children won't know what a grouper is because they are disappearing. Also sometimes, people use this poison from a local plant, they apply this poison on the holes of the rocks* (in the lagoon and intertidal zone) *and this damages a lot our environment. In fact, in the sea, I see the same thing that has happened on the earth. When I was a kid, we could see some antelopes, we don't anymore. Another example is with the hares, my children have never seen any whereas I saw so many when I was a kid. The same goes with samango monkeys!"- D6.*

Fishers also remarked on a decline in the numbers of nesting turtles returning to their beaches compared with previous times of great abundance (pre-1965). In both areas fishers referred to increased effort required to secure the same quantity (or less) of catch both fish and turtles.

Discussion

Survey respondents interacted with sea turtles on nesting beaches and in-water at Tofo and Dovela localities in southern Mozambique, however the nature of these interactions varied between fishing communities and areas. In Tofo, fishers reported interacting with turtles more frequently than in Dovela, however these interactions were primarily confined to in-water encounters. Tofo fishers described a historical (>10 years ago) targeted turtle fishery which is no longer active in the same capacity. A decline in turtle abundance and increase in deterrents (i.e. presence of tourists, occasional enforcement) in the fishery area were indicated by respondents as responsible factors for the reduced capacity of the Tofo turtle fishery. Dovela respondents only reported encountering nesting turtles (leatherback and loggerhead) which they hunted and nests from which they collected eggs. Dovela respondents described the hunting of nesting turtles as a traditional activity that no longer occurred, however egg collecting still takes place. In the 2014/2015 and 2015/2016 seasons, four nests were reported to be illegally harvested from this beach (Fernandes et al., 2015; 2016).

Traditional values regarding hunting of sea turtles were evident in Dovela but not in Tofo. They are described as a traditional slaughter and offering ceremony with village chief, hunters and the chief's grandchildren (detailed in Williams et al., 2016 - see appendix 3.2). A Dovela respondent recounted, "*My grandfather was the chief of the village so when someone caught a turtle, he had half of the animal*." He explained the system of allocation, in particular, the head of the turtle was given to the "regulo" (chief of the greater area) but half of the turtle was for the chief. One front flipper was allocated to the fisher who caught the turtle, the other front flipper and a hind flipper were provided to the leader, and the rest of the turtle was divided by the chief among those who had helped the catch. The Dovela respondent also explained that the chief of the village had to walk to the beach each time a turtle was caught and before dividing the pieces of the turtle. The chief would conduct a small ceremony with a machete “patting” on the shell of the dead turtle and saying “*Welcome, our ancestors gave this to us. Others have given this to us to sustain us.*” (For full details on traditions see: Williams et al., 2016 in appendix 3.2). Elder respondents from Dovela indicated that hunting and such ceremonies were prevalent pre-civil war, but no longer widely occurred. In contrast, respondents from Tofo, did not describe any traditional ceremonial activities or specifics regarding division of the turtle meat within the community. It remains unknown if my sampling failed to represent this, or if fishers in the Tofo area did not have or no longer practice traditional customs for sea turtle hunting and consumption.

My survey found that fewer livelihood opportunities were available to Dovela fishers, for example opportunities to sell their catches, to take advantage of inflated sales prices generated by tourism, or the ability to access alternative livelihoods. Overall my data indicate that in Dovela, the scale of illegal take is likely to be less than in Tofo because a Dovela respondent told me that hunting of turtles was temporarily restricted between October – March.

Relative to Dovela, Tofo could be described as an ‘open system’ containing a diversified community with tourism stimulating the local economy, with an enforcement presence and heavy fishing pressure (local and tourist game fishing). In Tofo many villages from the greater area (bairro or district levels) rely on accessing a select few locations to take and use marine resources. In these relatively developed areas (Tofo, Barra, Tofinho, Guinjata), I suspect a heavy fishing pressure occurs relative to the surrounding undeveloped areas. This is because additional fishing pressure comes from fishers travelling from non-coastal villages (e.g. Cumbana, ~ 50 km away from Tofo on N1 highway) to access marine resources to supplement their livelihoods. Therefore, the local infrastructure network (roads and public transport) indirectly lead to intensified fishing pressure at certain locations. Similar trends in Mozambique have been noted regarding access to markets, the establishment and expansion of bushmeat markets and post-war trade (Barnett 1998; Lindsey and Bento 2012).

The village of Dovela is isolated with limited road and access option and large areas of native vegetation still remain (Refer to Fig 1.2). Dovela and the surrounding area remain relatively undisturbed and undeveloped and are subject to reduce external influences (e.g. tourism, industry). A community hierarchy system remains in place with a traditional chief, a political chief and a regulo (chief of the greater area - Dovela and neighbouring villages - who is elected by the municipality). Respondents recalled traditional values relating to sea turtles. Dovela respondents indicated an awareness of environmental degradation from their own unsustainable fishing practices. For example;

> *"Compared to before, I find less and less fish, look at the groupers! There were much more before, the same for crayfish. For me, it is due to the increasing numbers of fishers and especially the divers. Line fishing has almost no environmental impact but spearfishing has and makes the fish drive back. The fishes went far from here because of those spear fishers"*- D7.

Participating older residents of Dovela suggested a decline in the numbers of nesting turtles coming to the area;

> "*At this time, (~1965) we could not count them (*nesting turtles*), there were too many coming to the beach*" – D8.

Respondent also remarked on the fact that the number of fishers has increased;

> "*There is less product nowadays but I think that the first reason for that is that there are many more fishermen than before"*- D2.

Drivers of illegal take

Based on responses from Tofo and Dovela I identified six main drivers for the illegal take of sea turtles: 1) culture and region; 2) food security; 3) poverty; 4) lack of alternative livelihoods; 5) enforcement; and 6) declining marine resources. These large-scale drivers appear to act synergistically (but not always). The drivers apply to not only to illegal take and use of sea turtles, but also to the larger scale problem of bushmeat hunting (Lindsey et al., 2013) and the rapidly expanding practices of unsustainable fishing (IFAD 2011; IDPPE 2013), issues which are prevalent in a number of developing countries (Alfaro-Shigueto et al., 2011; Jenkins et al., 2011; Cawthorn and Hoffman 2015). The effectiveness of interventions to decrease illegal take ultimately depends on the stakeholders' motives and drivers for engaging in an activity (Kühl et al., 2009; Kahler et al., 2012). Given that I found illegal take behaviour to vary between the two communities and among fishers, I suggest further investigations are needed to elucidate the behaviours of fishers participating in illegal take along other areas of the Mozambique coastline. This is particularly important in northern Mozambique where culture, traditions, language and religion vary notably from the south.

Motives for illegal take

I found multiple motives act to simultaneously to influence fishers to hunt turtles. At our study sites, motives for illegal take and use of sea turtles fell into five main themes: 1) fishing-related motives; 2) food security; 3) authority; 4) lack of livelihoods; and 5) cultural/traditional purposes. Motives for illegal take are not mutually exclusive and an individual poacher is likely to be motivated by more than one of these simultaneously or by different motives at different times in his life (as per Forsyth et al., 2013). I also found that motives for illegal take differed between Tofo and Dovela and varied among individuals (Hart et al. 2013 documents a similar pattern). Understanding the motives, and how they vary in and among villages and regions of coastal Mozambique, will be important for the effective management of sea turtles and other marine resources.

In both Tofo and Dovela the majority of fishers were opportunistic and prepared to hunt for turtle, dugong and other megafauna while fishing for other species. This behaviour has been noted in other locations (PNG: Marsh et al., 2015; Madagascar: Humber et al., 2014; Mexico: Mancini et al., 2011b). Fishers adopted a diverse variety of fishing techniques in each community and the type of gear used had varying degrees of by-catch risk to turtles. Thus the risk of opportunistic take through bycatch is likely to be highly variable on a national scale because the types of fisheries and the scales they operate at vary considerably along the Mozambique coastline (Pereira et al., 2014b).

In Tofo, my data revealed some evidence of a fishery targeting turtles. In particular, I found that there is a subset of fishers participating in targeted turtle hunting, who are a skilled minority group with a nomadic lifestyle. Mancini et al. (2011b) also reports on a similar group of transient fishers in

Baja California, Mexico. Respondents explained that these fishers move around depending on animal abundances and/or to avoid attracting too much attention from local fishers (arguments over usage rights (Mancini et al., 2011b), tourists, or enforcement). Moreover, these fishers were mostly spear fishers and did not exclusively participate in a targeted turtle fishery, many were also actively involved in shark finning. Hence my data reveal that it is likely that both turtle fishing and shark finning are intricately connected, especially given the lucrative nature of shark finning and relatively low value of turtle meat.

> "*You can't make that much money from catching turtles, it's better to catch big fish or sharks*" T12.

Observations from my beach transects (Chapter 4) support this, as pieces of shark carcasses were often found in fishing camps and amongst turtle carcasses. Further work is required to understand the motives of these specialist turtle/shark fishers group and quantify the prevalence of their occurrence and distribution on a national scale.

Changes over time (environmental, population)

There are many factors that influence the behaviour of small scale fishers in southern Mozambique. Much of the coastal population has experienced disenfranchisement, a residual symptom from the civil war. Coastal zones were less impacted (less militarised) by the civil war, during which the country's infrastructure and economy were halted. During this time much of the population had a heavy reliance on natural resources for food security, shelter and firewood and large areas of native bush were destroyed. Terrestrial animal stocks were severely depleted for bushmeat (Lindsey et al., 2013), which made coastal resources more appealing to refugees. The motives and drivers for illegal take I identified for sea turtles have similarities with bushmeat hunting and trade, all of which is collectively part of a larger issue across Africa.

Contributing to motives and drivers, coastal people have experienced displacement pressure caused by migration of people from the interior to coastal regions of the country (Dutton and Zolho 1990; Lopes and Gervásio 1999; Jaquet et al., 2010). The coastal zones are less impacted by dramatic seasonal changes and have a more hospitable climate/environment, which is also likely to have influenced migration to the coast. A consequence of migration is the loss of local ecological knowledge (LEK) required for sustainable coastal resource use. In the context of my two study sites, there have been significant increases in coastal populations in Inhambane Province post-war (INE 2010) and people flocked to coastal areas that host tourism hubs (e.g. Tofo) for improved livelihood options. Marked declines in total marine fisheries landings have been documented to coincide with the beginning of the civil war in 1976 (Jaquet et al., 2010). My respondents perceived a decline in catches of turtles, fish and encounters with nesting turtles in both areas. They indicated they had to adapt to these declines by increasing the extent of their usual fishing area, time spent and gear used (nets with smaller holes, and smaller hooks in line-fishing). Such changes to behavioural patterns that have also been noted in other SSF (Karnad et al. 2013) and can contribute to changes in pressure on marine resources.

From literature within the region: some similarities and differences

I found many similarities with the turtle fishery in Madagascar. The fishery in Madagascar can be described as a multi-species reef fishery or artisanal shark fishery in which traditional harpoons were superseded by spearguns, and fishers have increasingly turned to gillnetting (Walker and Roberts 2005). In both Tofo and Dovela, a similar multi-species reef fishery exists. However, Tofo has a greater prevalence of spearfishers than Dovela and the fishery targets a greater variety of marine megafauna. Interestingly, unlike Tofo, Madagascan fishers did not confess to targeting turtles exclusively, rather turtles were captured incidentally (Walker and Roberts 2005). Unlike Madagascar, my results returned no evidence to suggest that in-water turtle catches were highly seasonal (peak incidental turtle capture occurring from October to March) nor that gill net use is restricted to only the warmer months (October- March) (Walker and Roberts 2005). Whilst the heavy use of gillnets did not occur in Dovela, they were often used in Tofo and widely used throughout Mozambique (IFAD 2011; IDPPE 2013). In Madagascar, fishers explain that free diving with a spear gun is a difficult skill, similar to the traditional practice of using harpoons (Walker and Roberts 2005). In contrast, this gillnetting is a passive practice, requiring less effort on behalf of the fisher and thus favoured (Walker and Roberts 2005). I suspect that Mozambican fishers share the same opinion.

Although I did not ask respondents about the details of meat consumption, (i.e. how do they prepare the meat and how many dishes is turtle meat pivotal to) this kind of information would be valuable for assessing if and how substitutes for turtle meat could be incorporated into diets. While respondents were asked about the importance of the meat from their catches (not exclusively turtle), many indicated that high-value meats (game fish, crayfish, octopus) were prized for their sale potential and that household consumption of (any) meat did not occur daily.

> *"My wife does not want us to eat crayfish because she knows the value of it. So when I come back with unsold crayfish, she is angry and does not dare to eat an expensive meat!!"* – D2.

My assessment, based on the data I collected is that while turtle meat was once a semi-regular (festivities or ceremonies), or regular (subsistence) dietary item when it was widespread and abundant (at all coastal communities and potentially most households) consumption at this scale no longer occurs. If correct and the contemporary consumption rates and minimal cultural significance is accurate (particularly in Tofo), I suggest that improving turtle protection through outreach, education and alternative protein options is potentially feasible. Extensive community consultation would be required to confirm this and understand how interventions may need to differ between locations where cultural links remain.

Both language barriers and low literacy (and numerical skills) made accurate comprehension of participants' responses to the survey questionnaire difficult. I attribute low numeracy and literacy skills for the reason that many fishers struggled to quantify their responses (e.g. daily, weekly, monthly catch rates of fish, turtles or other megafauna). Given the shortcoming of the quantitative data on illegal take, other techniques are required to estimate the scale/quantity, distribution and impact of illegal take of sea turtles. Estimates from artisanal fisheries in Madagascar were thought to range from 11, 000 – 15, 000 turtles per annum (Hughes 1981; Rakotonirina 1987; Rakotonirina and Cooke 1994). However, recent work has estimated 10, 000-16, 000 caught per annum from Toliara, a single province in the south-west of Madagascar (Humber et al., 2011). Thousands of turtle bones littering the beach in front of Madagascan villages was clear evidence of many previous successful turtle fishing incidents (Walker and Roberts 2005). I have also noted evidence of this in sand dunes along the coast in Mozambique and surveying this may be a quantitative way to estimate the prevalence of illegal take and to overcome the absence of quantification in fishers' responses (Chapter 4).

Interview bias and clandestine interview subjects

My interview questions were designed to triangulate responses by asking multiple questions of a similar theme. However, sometimes answers provided do not align; an indication that perhaps the whole story was not being told. This is not unexpected with a subject that focuses on illicit behaviour and or the perception that livelihoods may be at risk (Mancini et al., 2011b). Some subtleties in individual responses were likely lost given the difficult nature of translating between three or four languages (Bitonga/ M'Chope, Portuguese and English). Another factor that may have influenced our interpretation of responses is the effect of the interviewer on the respondent. Given that I had to use multiple interviewers (for logistical and language/translation reasons), the interview bias could vary among interviews. It is also possible that fishers perceived one or more of our interviewers to be affiliated with their other employment duties, working with local conservation organisations, and this may have influenced respondents. I do not have data from Tofo about how many fishers declined to be interviewed, however in Dovela all fishers approached participated. In Tofo, spearfishermen were specifically targeted to participate because they were anecdotally known to be the primary turtle fishers (pers. obs.). Spear fishers are often considered a marginal group in fishing communities. Unlike other fishers, the spear fishers are not typically organised/structured into community groups (e.g. a community counsel of fishers (CCP's)). The CCP's were introduced by the government as part of a scheme to decentralise management efforts of fisheries resources. While

Dovela is too remote to have a formal CCP, traditional village leadership and hierarchy dictates some degree of informal management. In Dovela, respondent D9 explained the village has recently re-established the traditional act of monitoring and voluntary seasonal closures of mussel colonies, all of which is overseen by a newly appointed beach guard.

> "*If someone is caught harvesting, the fine is: one sheep, 20 litres of tontonte* (homemade alcohol), *25 kgs of rice and 3 kgs of sugar, but for catching a turtle, no fine*"- D9.

Conservation management and outcomes

While the drivers of illegal take of sea turtles are difficult to directly address, targeted conservation or management actions could be applied to address each of the thematic groups of motives identified. Preliminary outreach in Dovela has shown some positive feedback from the community (Appendix 4.3). Motives pertaining to authority could be addressed by an improvement in compliance either through governmental agencies or community-based initiatives (e.g. Humber et al., 2016 or Metcalfe et al. 2016). Food security and alternative livelihood motives could be addressed simultaneously through the programs exploring viability of more efficient small scale agriculture, permaculture or aquaculture. A successful village-based example of this occurs in south west Madagascar, where coastal communities have been trained and empowered through a sea cucumber mariculture programme as a way to offer alternative livelihoods (Robinson and Pascal 2009). Fisheries-related motives can be targeted through the introduction of catch and release schemes or sensitisation of fishers to turtle-friendly fishing gear (e.g. circle hooks or UV light on gillnets; Wang et al., 2010; Ortiz et al., 2016). I also suggest that making better use of new technologies (e.g. remote cameras mounted to observe SSF at docks or cameras mounted to frames on-board boats (Mangel et al., 2010; Thuesen 2016) or approaches to information gathering would assist understanding of SSF dynamics (e.g. Metcalfe et al., 2016). Cultural and traditional motives can be addressed through further investigation into the significance of the use of turtles and exploring the sustainability of implementing community based management strategies that build on traditional purposes.

Conclusion

I found the drivers of illegal take and use of sea turtles in Tofo and Dovela in southern Mozambique to correlate with large-scale problems common to many developing nations. However, the motives for illegal take are diverse and variable, within communities and among individuals (or an individual's lifetime). Fishing behaviour and techniques varied considerably between communities and therefore a single 'blanket' strategy to manage SSF is unlikely to achieve optimal results. Respondents had multiple motives and circumstantial factors that influenced their decision to fish for turtles. Social and cultural drivers of poaching varied between communities and are likely to be highly variable along the length of Mozambique's coastline. With this in mind, emphasis should be made to obtain a very good understanding of the socio-economic and cultural context before deciding on specific conservation management interventions (Swennenhuis 2011). Given that respondents expressed a lack of alternative livelihoods options to support them, poverty alleviation strategies and activities that diversify fishers' economic options may help to indirectly reduce illegal take of sea turtles.

Chapter 5 summary

- Illegal take of sea turtles is widespread in Mozambique. However, the extent, motives and drivers for take are poorly understood.
- This chapter described the socio-economic setting, motives and drivers of two coastal small scale fisheries in southern Mozambique (Praia do Tofo and Dovela), and the interactions these fisheries have with sea turtles.
- Based on fisher responses, illegal take of turtles within the study area occurs from both targeted hunting and opportunistic harvest.
- The primary reason cited by respondents for illegal take was for meat consumption.
- Respondents indicated opportunistic egg harvesting occurred however, most noted a recent decline in encounters with nesting turtles or nests.
- Based on the responses from fishers I suggest a linkage between overall community poverty levels, the lack of alternative livelihood opportunities, and illegal turtle take. Similarities in factors driving bushmeat hunting and illegal take of turtles in Tofo and Dovela were evident.
- Respondents were aware of the illegality of harvesting sea turtles but noted a lack of enforcement to deter them.
- Most fishers had more than one motive for engaging in illegal take.
- The dynamics of illegal take of sea turtles is complex. Motives and drivers can vary widely, even across small geographic areas.
- Only with improved understanding can we arrive at negotiating conservation interventions that are more socially, economically and environmentally sustainable.

Chapter 6

Using Expert Opinion to Identify and Determine the Relative Impact of Threats to Sea Turtles: A Case Study in Mozambique.

This chapter was designed to evaluate the current conservation context under which sea turtle conservation and management efforts operate within Mozambique. Chapter 4 and 5 suggest that illegal take and use of sea turtles could be a significant threat to local turtle populations. However, sea turtles face many other threats within Mozambican waters, for most of which published data is unavailable to conduct a thorough risk analysis. Thus, this chapter uses an Analytical Hierarchy Process to quantitatively rank and prioritise expert opinions on the most significant threats to turtles within the region. In this chapter I discuss the need for well-informed and adaptive management in Mozambique. I make recommendations for advancing and enhancing current conservation and management efforts under limiting conditions (funding, resources, capacity, political support). The chapter presents a framework/process for conservation managers in developing countries to quantitatively evaluate and prioritise current states of knowledge, and identify data gaps.

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Abstract

Although robust and consistent long-term datasets are lacking, it is commonly accepted that sea turtle populations face significant human threats while using Mozambique's coastal habitats. While multiple threats have been identified, their relative impact – and thus the ability to prioritize limited conservation resources– is poorly known. To obtain a better understanding of these threats, I elicited information from experts through a semi-structured survey using a mix of open and closed-ended questions (n = 24 questions). Experts in research, conservation and management of sea turtles were identified (n = 18) and asked to identify key threats and to complete pairwise comparison matrices to determine the relative weight (w) of each threat (13 criterion). Weights for the perceived impact of threats were calculated from scores given in the pair-wise matrix using Analytic Hierarchy Process (AHP). A total of 73% of potential experts (n = 18) responded to my surveys. Bycatch from trawling (w = 13.65), artisanal fishing (w= 12.30), and hunting of nesting turtles (w = 11.33) were the top threats identified. Responses to open-ended survey questions were thematically coded and I discuss common themes (e.g. extent of knowledge, limitations, conservation management tools) identified. I found that, given a lack of baseline or published data, soliciting expert opinion was an efficient way to identify emergent threats, along with the success and limiting factors influencing sea turtle conservation in a developing nation. This technique can provide valuable insights in locations with similar socio-economic environments and limited empirical data.

Introduction

Marine megafauna tend towards conservative life history characteristics (long lived, late maturity) and are often highly mobile (wide ranging, migratory, ontogenetic habitat shifts). These factors combine to make the accurate assessment of their conservation status pressing, but challenging. Management plans can be particularly difficult to formulate in developing countries, which often contain the highest biodiversity (Brooks et al., 2006) and face the greatest threats (Baillie et al., 2004), yet are hampered by scarce biodiversity or threat baseline data (Lundquist and Granek 2005). Where detailed studies are unavailable, alternative approaches may be usefully applied to overcome knowledge deficiencies. Here, I surveyed sea turtle experts in Mozambique to identify, prioritise and determine the relative impact of anthropogenic threats to sea turtles in Mozambique. I discuss these findings in regard to the relevant socio-political factors influencing sea turtle conservation in the country.

Limited local empirical knowledge exists on the five species of sea turtles (loggerhead (*Caretta caretta*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*) and olive ridley (*Lepidochelys olivacea*)) that use Mozambique's coastal waters (Louro et al., 2006). With the exception of olive ridley turtles, these species all nest within the country. Loggerhead and leatherback sea turtles use the sandy beaches of southern Mozambique and the contiguous northern Kwa-Zulu natal coast of South Africa as a nesting rookery (Fernandes et al., 2016). Green and hawksbill turtles use northern Mozambique as nesting grounds. Mozambique's coastal waters are important foraging habitat for two of three green turtle regional management units (RMU's) (Bourjea et al., 2015). Information about hawksbill genetic stocks are not specifically known, although it is thought they belong to a single WIO RMU (Mortimer & Donnelly

2008). Loggerheads in the WIO region belong to a single genetic stock (Shamblin et al., 2014; Nel and Casale 2015). Each of the RMU's, regardless of species, are shared resources between neighbouring countries of the WIO. Major data gaps exist regarding the population status and distribution for each species (IUCN 1996; Wallace et al., 2011). In addition to poor biological baselines, anthropogenic threats to each species are not well understood at the level of each WIO nation (e.g. Kenya (Okemwa et al 2004), Madagascar (Rakotonirina and Cooke 1994; Walker and Roberts 2005), Mozambique (Louro et al., 2006, Fernandes et al., 2016), Tanzania (Muir 2005) South Africa (Harris et al., 2015) and across the region (IUCN 1996; Bourjea et al., 2015).

Although specific data are lacking, it is commonly accepted that regional sea turtle populations face significant human threats while using Mozambique's coastal habitats (Louro et al., 2006). The relative impacts of these threats are unknown. This hampers management ability and confidence to prioritise limited conservation resources to achieve effective outcomes. Indeed, a global assessment of status and threats criteria indicate that sea turtle Regional Management Units in the Indian Ocean had the highest average data uncertainty scores for both risks and threats, and that critical data needs occurred frequently (Wallace et al., 2011). To address this, I obtained information on key threats and their relative impacts to sea turtles in Mozambique using information solicited from expert opinions. I also explore issues surrounding the conservation of a charismatic and flagship marine species in Mozambique.

Methods

Study Area

Mozambique is ranked 180/188 on the Human Development Index (UNDP 2015) and scores poorly on the global corruption (score 31/100, rank 112/167 (Transparency International 2016) and governance indexes (Kaufmann and Kraay 2015)). Despite having one of the world's fastest-growing GDP's since 2001, the measures of inequality and illiteracy are high and the GDP per capita, along with average life expectancy, are amongst the lowest in the world. These factors are likely to influence the success of conservation efforts.

Expert Survey

I used an expert survey to inform conservation management of sea turtles in Mozambique. Expert knowledge has been widely used to assess the relative impact of ecosystem-stressors when comprehensive empirical data are scarce (e.g., Halpern et al., 2007; Pascoe et al., 2009; Fuentes et al., 2011). Specifically, expert knowledge can be used to rank and prioritize human threats to inform conservation planning (Wallace et al., 2011; Gretch et al., 2012; Fuentes et al., 2013). Here I used expert elicitation paired with multi-criteria decision tools to synthesize expert opinions, while also assessing the uncertainty around those views; a technique that has been widely adopted across disciplines (e.g. Aipanjiguly et al., 2003; Teck et al., 2010; Huang et al., 2011; Donlan et al., 2010). Experts comprised of managers and scientists with an extensive or intensive knowledge of; Mozambique's sea turtles, threats, policy, the conservation management efforts focused on addressing these issues. I identified 18 potential respondents through attendance at an Indian Ocean South East Asia (IOSEA) regional meeting (IOSEA Marine Turtle Memorandum of Understanding) and application of a snowball approach, whereby other potential respondents were suggested by the experts (Goodman 1961, Biernacki and Waldorf 1981). Thirteen of these experts participated in the survey. The majority of the surveys were conducted via email, with my contact details provided in case the respondent had any queries. A small proportion of the surveys were conducted individually, face-to-face (n = 2) as participants were not confident with their written English skills. The survey had a total of 24 questions (Appendix 6.1) and took, on average, an hour to be completed. The survey included a description of the project and a summary of key aspects of research questions. Basic descriptive information about respondents (their organisational affiliation, country of employment, years of relevant experience and experience with Mozambique) was collected. Information was solicited from the experts via: a) pairwise comparison threat matrix, to quantitatively documented threats and their relative impacts, along with b) an open-ended questionnaire to document and understand how socio-economics and governance influence conservation and management efforts in Mozambique.

Threat matrix.

Prior to developing the survey, I identified the main threats known to affect sea turtles within Mozambique or the greater WIO region. The threats were identified from the IOSEA regional meeting discussions and a literature review (IOSEA 2012). Thirteen threats were identified: 1) hunting of nesting turtles (Hughes 1971; Humber et al., 2016); 2) egg harvest; 3) direct hunting of foraging turtles; 4) bycatch commercial fisheries (long-lining); 5) bycatch commercial fisheries (trawlers) (Gove et al., 2001; Louro et al., 2006; Mellet 2015); 6) coastal habitat modification (including artificial lighting) (Louro et al., 2006; Hughes et al., 2007); 7) vessel strike; 8) hunting of foraging turtles (opportunistic turtle fishers); 9) bycatch from artisanal fisheries (Louro et al., 2006; Whitty et al., 2010; Mellet 2015); 10) plastic debris (Hoarau et al., 2014; Schuyler et al., 2015); 11) climate change - temperatures; (Hays et al., 2003, Hawkes et al., 2009, Fuentes et al., 2013); 12) climate change - sea level rise) and 13) climate change - cyclones) (see Table 6.1 for description of threats). Within the survey, I asked each expert to independently complete a pairwise comparison matrix that contained the 13 identified threats in order to determine their relative weights (w). Experts could assign seven different scores to each comparison of two threats, ranging from extremely important to equal importance (Table 6.2).

Table 6.1. Mean weights and ranking of respondents from an analytical hierarchy process. Weight represents the perceived impact of a threat, while rank shows how much variation exists among the threats.

Threat criteria	Description	Weight	Rank
Bycatch - trawl	Commercial fisheries trawling	13.65	3.70
Bycatch - artisanal	Artisanal fisheries (gill nets, purse seining, hand-set long lines, beach seining)	12.30	3.50
Hunting of nesting turtles	Hunting while turtles are on nesting beach, or emerging from or returning to water.	11.33	4.50
Bycatch long line	Commercial fisheries long liners	9.14	5.60
Global climate change - sea level		8.77	6.50
Direct hunting - foraging turtles	Targeted hunting for turtles, frequently spear fishers	7.61	6.70
Global climate change - temperatures		7.15	2.00
Egg harvest		6.50	8.50
Coastal habitat modification	Including artificial lighting & driving on beach.	6.23	7.20
Global climate change - cyclones		5.76	7.50
Plastic debris		3.92	9.90
Indirect hunting foraging turtles	Opportunistic hunters who capture turtles if they encounter them	3.80	7.10
Vessel strike		0.70	10.50

Table 6.2. Survey scale used to compare two threats against each other to build a threat matrix (comparison of 13 threats in total).

Threat A			=	Threat B		
9, 7	5	3	1	3	5	7, 9
Extreme importance	Strong importance	Moderate importance	Equal	Moderate importance	Strong importance	Extreme importance

Open-ended questionnaire.

Experts were asked about the threats they perceived to impact turtles within Mozambique and also about any relevant data gaps. I also asked experts to define the role of various agencies in current and future conservation and management efforts. Additionally, experts were asked to identify the resources required to improve current efforts, and the most important factors to advance management strategies.

Analysis

Weights for the perceived impact of identified threats were calculated from scores given in the pair-wise matrix using Analytic Hierarchy Process (AHP) (Saaty 1980) and the AHP priority calculation software (available at http://bpmsg.com/academic/ahp.php (downloaded 29/01/2015). AHP is a multi-criteria decision-making method that derives weights paired comparisons from principal Eigen vectors (Saaty, 1980). Each of the respondents' scores were entered into the comparison matrix and analysed separately. The calculation software gives a consistency ratio (CR) score, priority ranking output table with ranking, weight % and the decision matrix of principal Eigen vectors (Table 6.3 for an example of output). I averaged the weights and rank values of each threat criterion per respondent to obtain an overall weightings and threat rankings (Donlan et al., 2010; Fuentes and Cinner 2010; Fuentes et al., 2013). The CR metric was used to assess the consistency of experts' responses in relation to a large sample of purely random judgements (Goepel 2013). Open-ended questions were analysed using qualitative data analysis software nVivo 11. Common themes and patterns in responses were summarized and tallied for each topic/section, and alternative responses were noted (Patton 1990).

Table 6.3. Example AHP output for a pairwise comparison between three threats; hunting, bycatch- commercial trawling fisheries and vessel strike. Selection of importance level of A or B factor threats is shown in grey. Score column then represents how much more important (1-9) that threat is according to the survey scale in Table 6.2.

Importance A?	Importance B?	Score
Hunting	Commercial fisheries-trawling	5
Hunting	Vessel Strike	9
Commercial fisheries-trawling	Vessel strike	9

Category	Rank	Weight %	Matrix	Hunting	Commercial fisheries-trawling	Vessel strike
Hunting	2	24.5	Hunting	1	0.20	9.0
Commercial fisheries-trawling	1	71.1	Commercial fisheries-trawling	5	1	9
Vessel strike	3	4.6	Vessel strike	0.11	0.11	1

Number of comparisons	3	Principal Eigen value	3.295
Consistency ratio	30.8%	Eigenvector solution: 7 iterations, delta	1.5E-8

Results

Respondent Demographics

Half of respondents (54%, n = 7) identified their affiliation with non-governmental organisations (NGO's), two with universities (15%), one from government (8%), one from a non-profit organisation (NPO) (8%) and two identified as the 'other' category (15%). The majority of experts were residents of Mozambique (70%, n = 9), with the remaining 30% of experts working within the region (Tanzania, Kenya, South Africa and/or Reunion Island) and had worked within Mozambique previously and/or in collaboration with Mozambican practitioners. Expert experience level ranged from 2 years to more than 20, with a mean of 9.

Extent of Knowledge and the Perceived Impacts of Threats

Specialist knowledge on sea turtle conservation biology and management issues within Mozambique was limited to a small number of experts. The number of potential relevant experts identified to contact for participation was small (n = 18). Of this, 72 % participated in the study (n = 13). Low representation between respondent groups, i.e. government and other stakeholder group types prevented inter-group comparisons of threat rankings. The 13 threat criteria were considered comprehensive and representative of issues impacting sea turtles in Mozambique. In addition to these, one new emerging threat and one process was proposed by experts: increase in predation rates by native species, (i.e. honey badgers (*Mellivora* *capensis*)), triggered by reintroduction, and coastal immigration leading to coastal human population increase.

Key Threats to Mozambican Turtle Populations

A total of 77% (n = 10) of experts completed the pairwise threat comparison matrix. The top threats identified were: bycatch from trawling (w 13.65, rank 3.70), artisanal fishing (w 12.30, rank 3.50), and hunting of nesting turtles (w 11.33, rank 4.50) (Table 6.1). Threats of least concern (by weight) were plastic debris, indirect hunting for foraging turtles, and vessel strike. The ranking and weighting of threats was similarly spread, and both ranking and weight scores lacked distinctive groupings, with the exception of vessel strike which was noticeably separate. Consistency ratio scores per respondent ranged from 12.1% to 59.6%, and the mean score was 27.73%.

The majority of experts were aware of all (69.23%) or most (23.07%) of the illegal take and use activities (direct harvest of turtles through spearfishing or hunting) occurring in Mozambique. The impact/threat of egg or meat consumption were perceived to be different across turtle species. However, mean ranking scores revealed a consensus that green turtles were the most affected population from both egg and meat consumption (Table 6.4). Threats to leatherback and olive ridley turtles based on level of impact to the species from egg consumption or meat consumption were perceived differently by experts. Additionally, several experts expressed concern regarding the bycatch rates of industrial and semi-industrial fishing. In addition to this, IUU (illegal, unregulated and unreported) fishing was also mentioned as an unquantified yet potentially significant threat, within the region.

Table 6.4. Mean ranking scores assigned by experts for turtle species most effected by meat and egg consumption, where scale was 1- very affected to 5- least affected.

Egg Consumption	Mean	% Response	Consumption of Meat	Mean	% Response
Green	1.500	61.53 (n = 8)	Green	1.556	69.23 (n = 98)
Loggerhead	2.250	61.53 (n = 8)	Loggerhead	2.556	61.53 (n = 8)
Hawksbill	2.500	61.53 (n = 8)	Hawksbill	3.000	69.23 (n = 9)
Leatherback	3.500	61.53 (n = 8)	Olive Ridley	3.429	53.84 (n = 7)
Olive Ridley	4.000	46.15 (n = 6)	Leatherback	3.625	61.53 (n = 8)

Stakeholder Involvement

The majority (84.61%) of experts strongly agreed that conservation initiatives within Mozambique are necessary for maintaining WIO regional turtle populations. Most experts (92.30%) were aware of specific legislation that existed for sea turtles within Mozambique. Generally, experts (69.23%) felt that it was necessary to strengthen legal initiatives to improve management of sea turtles within the country. A portion of experts were unsure (23.07%), or did not agree (7.69%) that strengthening legal initiatives would benefit sea turtles. Additional comments were added by 46.15% of respondents referring to the need to improve the application and enforcement of existing laws.

Experts considered the role of the Mozambican Government to be extremely (69.23%) or moderately (7.69%) important in sea turtle conservation and management. Additionally, all experts valued the role of non-government organizations as moderately (30.76%) or extremely important (69.23%) to sea turtle conservation efforts. The majority of experts were aware of the ‘Mozambican marine turtle working group’ (Groupo de Trabalhar de tTartaruga, (GTT)) and recognized that an active GTT would be moderately (23.07%) or extremely (69.23 %) valuable in advancing conservation and management efforts.

Factors to Improve Conservation Management Efforts

Numerous concepts were identified by the experts as crucial to improve current conservation, enforcement or management efforts in Mozambique. Experts felt that multiple actions would need to be implemented simultaneously to improve conservation efforts. The actions fall into 8 main groups (Table 6.5), and cover a broad variety of themes (e.g. enforcement, outreach and politics, capacity building). However, experts felt that emphasis needed to be placed on improving enforcement efforts, increased human resources and stable funding (Table 6.5).

Table 6.5. Concepts voiced by experts (and % count) to progress existing efforts of sea turtle conservation in Mozambique. Top ranking ideas (mode) for improving conservation and management efforts are highlighted in bold.

Theme/topic	Idea	% count of respondents
Enforcement & training	**Improve enforcement by training enforcement officers of laws relevant to conservation (i.e., officers, prosecutors, district, police).**	**61.53 % (n = 8)**
	Increase coordination and communication between stakeholders involved with enforcement.	23.07% (n = 3)
	Adoption of technology to aid law enforcement and patrols.	7.69% (n = 1)
	Effective and visible patrolling and enforcement by relevant authorities.	23.07% (n = 3)
Education	**Educate public about turtles and their protection.**	**38.46% (n = 5)**
Community Livelihoods Involvement	Identification of alternative livelihood sources for local communities.	15.38% (n = 2)
Awareness	Heightened respect by new investors towards local communities, their traditional knowledge, cultures and resource usage rights.	7.69% (n = 1)

	Increased involvement and capacity building of local communities for conservation and management initiatives (incl. ecotourism & research).	15.38% (n = 2)
Resources	**Increase human resources and funding.**	**53.84% (n = 7)**
Conservation planning/ Science	Need to identify hotspots and prioritise limited resources towards these areas.	7.69% (n = 1)
	Increased research, monitoring and dissemination of results to better understand population status and threats at national level.	23.07% (n = 3)
Training	Identify and train conservation leaders.	7.69% (n = 1)
	Greater government involvement.	23.07% (n = 3)
Political	Increased status of turtle conservation on political agenda/ national commitment.	23.07% (n = 3)
Outreach	Engage tourism sector in enforcement or citizen science by supplying information.	7.69% (n = 1)
	Increased PR and national media on the number of offenders, their respective fines and reports of their completed prosecution.	7.69% (n = 1)

Discussion

Key Threats

Bycatch from commercial trawlers (1st), bycatch from artisanal fishing (2nd) and hunting of nesting turtles (3rd) were perceived as the most pressing threats to turtles in Mozambique. According to the weightings, experts considered these top threats to be similarly detrimental. It is likely that these threats are also relevant at the WIO regional level to all sea turtle species (IUCN 1996). Mozambique (50-95; Brito 2012) has the highest number of vessels in its shallow water prawn trawl fishery (cf. Madagascar (42; van der Elst and Everett 2015), Tanzania (22; Muir 2005), Kenya (4-20; Mwatha 2003), South Africa (3-7; van der Elst and Everett 2015). Bycatch from commercial trawling has been thought to be one of the greatest sources of sea turtle mortality in Mozambique since the 1990's (Louro et al., 2006; Gove et al., 2001; Pereira et al., 2014a). Commercial trawling for penaeid prawns is focused on two areas: around Maputo Bay (in the south) and Sofala Banks (in the central region) (Brinca and Palha de Sousa 1984; Tomás, 2001). Estimates of bycatch are limited, however the scale of the fishery (Brito 2012), and therefore the impact of the Sofala Banks fishery, is thought to be greater than Maputo Bay. Annually, the Sofala Bank prawn fishery is estimated to catch between 1 932 to 5 436 sea turtles (Gove et al., 2001), which is significantly greater than Kenya's annual bycatch estimate of 500 to 1000 (Wamukoya et al., 1997). Sporadic records of commercial trawling-associated mortality have also been reported in Maputo Bay (two of South Africa's vessels use this fishery area) and Bazaruto Archipelago (MPA area). However, annual bycatch estimates are unavailable (Guissamulo 1993). Additional data are required to quantify the impact of this fishery in all areas of active operation within Mozambique

Although the requirement for Mozambican trawlers to use turtle excluder devices (TEDs) was legislated in late 2003, implementation (and enforcement) of the TEDs has not occurred to date (Brito 2012; Pereira et al., 2014c). This is unlike the situation in Madagascar in which TEDs were implemented and have been enforced since 2005 (van der Elst and Everett 2015), with their use resulting in a substantial reduction in sea turtle mortality

(Rakotonirina et al., 2006). There are also other examples of both developed and developing nations which have implemented TED use in trawl fisheries, with similar reductions in bycatch (Epperly 2003; Fennessy et al., 2008). The technology and capacity to design TEDs for a variety of trawl fisheries exists, and several fisheries agencies provide training in installation, use and enforcement. This chapter indicates that bycatch in trawl fisheries is a key threat to Mozambique's sea turtles. Given the successful use of TEDs elsewhere in the world, I believe that strengthening the TED policy and enforcing their use in Mozambique would be relatively straight forward, compared with to other identified threats, many are spatially, temporally and socially more complex to solve.

Artisanal fisheries are widespread throughout the entire ~ 2 700 km of coastline and adopt a variety of techniques, including beach seining, purse seining, gill netting, hand-set long lines, fish traps, spear fishing and intertidal zone collecting. Across the entire WIO region, inadequate scientific knowledge restricts effective management of artisanal fisheries (van der Elst and Everett 2015). Previous mortality estimates caused by artisanal fisheries was 240 – 420 turtles per annum in Mozambique (75% of that *C. mydas*) (Louro et al., 2006) however I believe this figure is lower than the current catch. Beach seining alone (considered in Inhassoro, Inhambane Province) is estimated to impact 160- 280 turtles annually over a single 8-month fishing season (Gove and Magane, 1996; Hughes, 1971; Magane et al., 1998). Although the impact of gillnet bycatch has not been quantified, it is expected to be high, given more than 43 000 nets are thought to be in use (IDPPE 2013; MIPE 2013). Bycatch from the other artisanal fishing methods are unknown. In Madagascar, estimates of sea turtle catches by artisanal fisheries vary from 11 000 to 15 000 per year (Hughes 1981, Rakotonirina 1987; Rakotonirina and Cooke 1994). However, most recent estimates from a single province in SW Madagascar demonstrated turtle catches to be 10 000 to 16 000 (Humber et al., 2011). Applying these Madagascar studies as a proxy for the Mozambican situation, it is likely that artisanal fisheries have a major impact on Mozambican sea turtles.

Hunting of nesting turtles was also considered by experts as a significant threat to Mozambican sea turtle populations. This is a traditional activity that was previously considered to be low impact, given the cultural restrictions surrounding its practice (Louro et al., 2006). High numbers of sea turtle mortality reported at the end of the colonial period (Hughes 1971) and a protracted civil war (16 years) are thought to have exacerbated hunting for bush meat (Lindsey et al., 2013) and “marine bush meat” (Alfaro-Shigueto and Van Waerebeek 2001). Sea turtle mortality rates are assumed to have increased as the degradation of cultural and traditional ecological values occurred throughout the 1980’s and 1990’s as a consequence of war (Louro et al., 2006). Direct exploitation of turtles for eggs, meat and carapaces has been documented (Costa et al 2007; Videira et al., 2008) but quantification of its impact at hotspots, provincial and national scales has not been conducted. Experts perceived threats from egg and meat consumption to differ across species. Experts rankings of impacts from egg and meat consumption was scored from most to least impacted as green, loggerhead and hawksbill, possibly reflecting population sizes or ‘availability for take’ within the SWIO. However, scoring variation occurred between leatherback and olive ridley which may reflect uncertainties about the status of populations. Variation in perceived impact from consumption of turtle eggs or meat may reflect diffing taste preferences between species however this needs to be evaluated further in future work. Current reporting of illegal take is temporally and spatially sporadic, with a focus on southern Mozambique (Fernandes et al., 2015; Fernandes et al., 2016).

Experts perceived threats of least concern to the region as: vessel strike (13th), indirect hunting of foraging turtles (12th) and plastic debris (11th). Two additional threats were identified by experts; coastal migration and population growth (an anthropogenic threat) and increased levels of predation by reintroduced honey badgers (a natural ecological threat). Part of the justification for including the latter process as an emerging threat is the lack of traditional ecological knowledge in new migrants, particularly an absence of understanding sustainable resource use patterns. Additionally, experts identified an emerging threat as the increased levels of nest predation by honey badgers, triggered by their reintroduction/recolonization of terrestrial wilderness areas in the trans-frontier conservation area (TCA). Regardless, experts agreed that basic information on threats and turtle populations are lacking, hindering threat assessments and understanding of the full impacts.

Expert Opinions

There are few experts with specific knowledge of sea turtles working within Mozambique. Although the survey engaged additional experts from the broader WIO region, there were still many obvious data gaps, implying that fundamental information is absent. Expert responses reflected this uncertainty, with variability in the perceived impacts of threats and challenges, and in subsequent prioritisation. This is supported by the high consistency ratio scores, a metric designed to demonstrate inconsistency/uncertainty in expert responses while ranking threats. Experts expressed concerns for the implications to turtle RMU's within the greater WIO if Mozambique failed to address and manage its top threats in a timely manner. Of concern, many of the data gaps highlighted by experts are also applicable across the greater WIO region, and were identified and summarised twenty years ago (IUCN 1996).

Experts reported that within Mozambique the wealth of expertise resides within NGO's, NPO's and universities. The importance of these types of stakeholders was noted, not only for their skills and knowledge, but for their access to different funding sources, (e.g. private sector). Experts perceived research and enforcement efforts to be predominantly led by NGO's. In addition, they perceived a lack of support for these efforts from government, and that the government was not prioritising biodiversity and conservation issues. Previously, the focus of the Mozambican government was described as aligning with poverty reduction strategies, rather than environmental sustainability (Pierce et al., 2010). However, experts emphasized the importance of having the government engaged, active and involved in sea turtle conservation and management. It was commonly recognised that relevant government departments had limited resources allocated to them and low technical capacity to execute their tasks. This has also been reported with regards to artisanal fisheries and their management within Mozambique (Swennenhuis 2011). Within the experts, only one respondent was affiliated with government and thus some bias among expert groups (affiliations) was possible. However, I was unable to identify additional experts working within the public sector. Finally, experts expressed that the sea turtle working group (GTT) should be an important and unified group for coordination, collation information, dissemination and lobbying. For the GTT to be effective and influential, experts the group would need to be actively fundraising for the national sea turtle conservation, research and monitoring program.

All experts considered stable and ongoing funding to be a key input required to progress efforts, and regarded the past and present lack of stable funding as a major limitation to achieving effective conservation outcomes. It is clear that strategic research and a conservation management plan for sea turtles are required. Given the emphasis experts placed on the lack of enforcement activity, it was proposed that targeted capacity-building and awareness campaigns are required for personnel with jurisdiction to enforce sea turtle legislation.

Management Implications

Although Mozambique introduced specific protection legislation for sea turtles in the 1960's, application of the law, and the allocation of resources and capacity to support it, could be improved. Experts clearly identified that enhanced enforcement efforts are critical, (i.e. increasing the number of locations patrolled, frequency of patrols, distances covered and openly disseminating the results of such efforts to the general public). Enforcement of fisheries legislation has previously been reported to be weak within the country, causing conflicts with both the tourism and conservation sectors (Swennenhuis 2011). Additionally, experts felt it was necessary to have clearly defined roles for all stakeholders, with the desired outcome being an increase in collaboration. The existing legislation regarding sea turtles was considered sufficient, in that it comprehensively protects sea turtles in a variety of situations, but it is unclear (in practice and in legislation) as to which government sector or department has the responsibility to administer and enforce legislation. Combined with an absence of technical expertise within regional or provincial departments, this often results in a lack of institutional ownership of sea turtle conservation, leading to inaction. One expert reiterated;

"*I think all the tools and ideas are there, it's more a question of implementing them properly*."

Targeted capacity-building with management and enforcement staff on turtle legislation, biology, ecology and threats, along with recruitment and training of additional enforcement staff, were key recommendations. Increased public engagement was also considered a necessity, with a suggestion to add turtle information to the national secondary school science curriculum. Community integrated and community led conservation initiatives (including alternative livelihood development and ecotourism) were regarded by the expert group as valuable actions and should be encouraged (Grayson et al., 2010; Swennenhuis 2011). Finally, experts emphasised the importance of prioritising efforts and directing actions within hotspot areas. Given that information on turtle threat hotspots is currently scarce, resources need to be allocated towards identifying the areas that require dedicated attention. Many of the threats, data gaps or constraints considered to hamper conservation and management efforts of sea turtles are also applicable to the conservation of terrestrial fauna (e.g. lions), and have already been recognised in the 'Conservation Strategy and Action Plan for the African Lion (*Panthera l. leo*) in Mozambique' (Fusari et al., 2010).

Conclusions

The majority of knowledge on sea turtle ecology and threats within Mozambique comes from leatherback and loggerhead turtle nesting populations in the trans-frontier conservation area (TCA) in the far south of the country. Experts highlighted that significant data gaps exist for central and northern Mozambique. Simple extrapolations of threats to these regions is not appropriate, as the TCA lacks a human coastal population reliant on marine protein sources. Overall, the threats perceived to have the highest impact by contemporary experts remain poorly understood. A conservation strategy and action plan for WIO sea turtles was devised twenty years ago (IUCN 1996). Sadly, most data gaps identified in that document are still relevant, and little overall progress has been achieved toward addressing those gaps. Ultimately, a more inclusive, adaptive management process is clearly required, incorporating managers at district and community levels, along with technical experts and government officials. A monitoring and evaluation feedback loop would encourage periodic progress assessment, facilitating the advancement of conservation efforts beyond the simple identification of data gaps (Robert and Hamann 2016). Finally, I encourage technical specialists to ensure that managers are well-informed on current science and emerging technologies to enable informed decision-making, and for managers to seek out the opinions of experts and technical specialists.

Chapter 6 Summary

- Sea turtle populations face significant human threats while using Mozambique's coastal habitats. While multiple threats have been identified, their relative impact – and thus the ability to prioritise limited conservation resources– is poorly known.
- To obtain a better understanding of these threats, I elicited information from experts through a semi-structured survey using a mix of open and closed-ended questions (n = 24 questions).
- Experts (in research, conservation and management of sea turtles) were identified and asked to identify key threats and to complete pairwise comparison matrixes to determine the relative weight (w) of each threat (13 criterion).

- Bycatch from trawling (w = 13.65), artisanal fishing (w= 12.30), and hunting of nesting turtles (w = 11.33) were the top threats identified.
- Experts clearly identified that enhanced enforcement efforts are critical to improve conservation of sea turtles within Mozambique.
- Given a lack of baseline or published data, soliciting expert opinions was an efficient way to identify emergent threats, along with the success and limiting factors influencing sea turtle conservation in a developing nation.
- This technique can provide valuable insights in locations with similar socio-economic environments, and limited empirical data.

Chapter 7

General Discussion

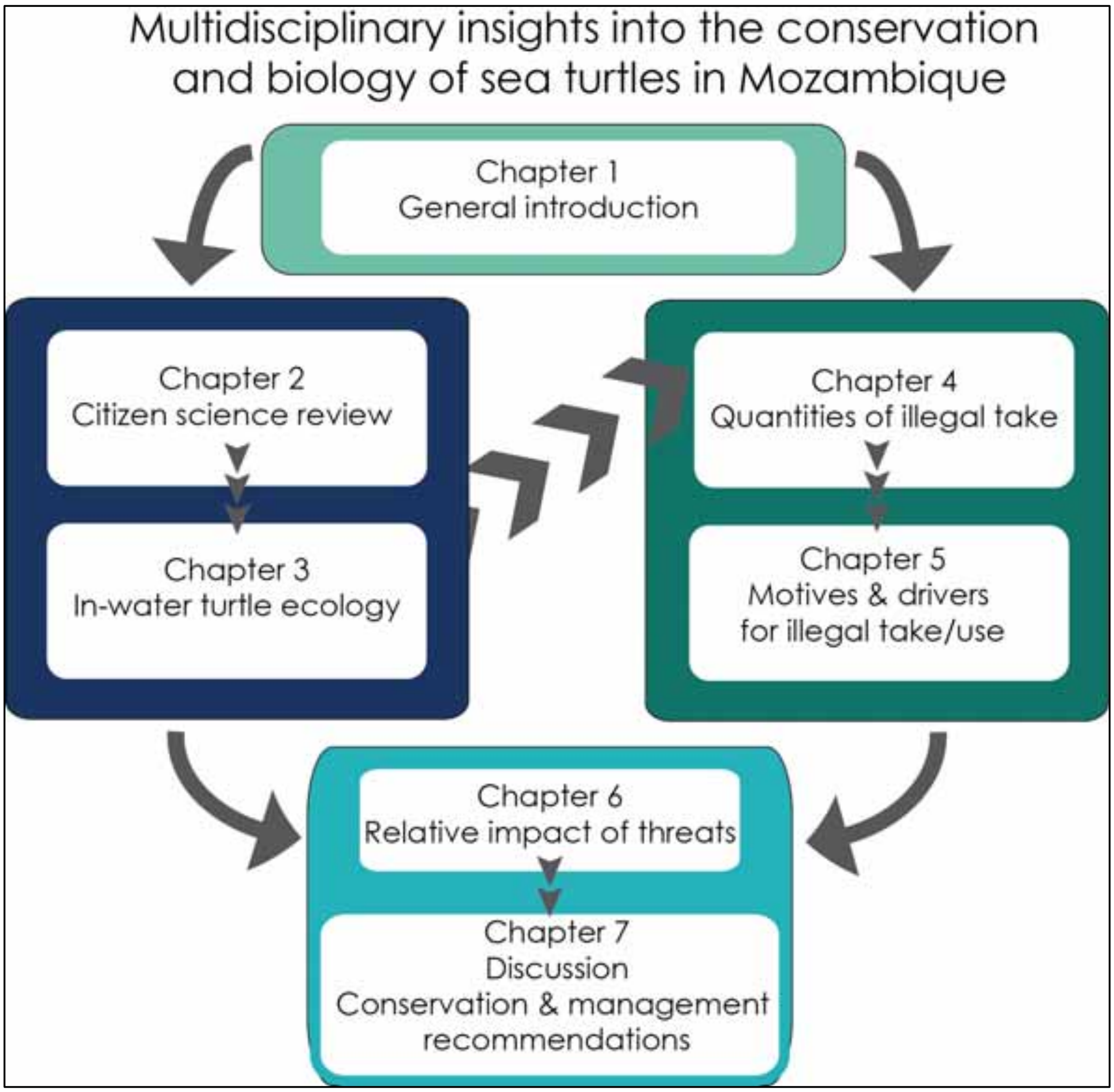

Fig.1.1. Thesis structure diagram

Opportunities to enhance conservation and management of sea turtles in Mozambique

Information to guide effective conservation and management of sea turtles in Mozambique is lacking. While Mozambique is thought to provide important foraging and nesting habitats for all five species of sea turtles that occur within the South Western Indian Ocean (SWIO) (Hughes 1971), fundamental baseline knowledge on their population demography, spatio-temporal patterns and how these species interact and respond to numerous and widespread anthropogenic threats, is absent or scarce (Louro et al., 2006). Given the relative importance of Mozambican habitats to regional populations and the prevalence of threats, my thesis was undertaken as an important first step to begin to address some of these extensive data gaps (biological, threats and socio-economic) and compile existing information from the literature. The primary focus of this thesis was to understand how sea turtles use the coastal waters of southern Mozambique, and if animals using these areas are impacted by illegal take and small scale fishing.

My research focused on a case study at Praia do Tofo on the Inhambane peninsula, southern Mozambique. Obtaining, collecting, and contributing information on sea turtles, their threats and the socio-economic influences driving such threats is critical to the formulation of future conservation plans and effective management of the taxa. Particularly in Mozambique as pressures on sea turtles and coastal environments increase. Specifically, my goals were to 1) develop techniques to enable baseline data collection of turtles in-water, 2) use dive-based citizen science data to understand the use of coastal Mozambican waters by sea turtles, 3) quantify the extent of illegal take and identify key areas where this occurs, 4) identify motives and drivers influencing illegal take and use, 5) identify and rank the main threats to Mozambican turtles , and 6) highlight key data gaps and identify factors influencing conservation and management efforts (box 7.1). The overall purpose of this thesis was to improve and advance the science, conservation and management efforts of sea turtles within Mozambique, and to use the new information to inform and build capacity with local authorities, stakeholders and communities. In this final thesis chapter, I will briefly review the main findings of my thesis by summarising responses to my five research questions (box 7.1). Additionally, I discuss management implications and directions for future research.

Viable baseline monitoring techniques & understanding the population structure of sea turtles:

1. *How can in-water turtle populations be monitored in a cost-effective way? (Chapter 2)*
2. *Can dive-based citizen science be used to understand how Mozambican coastal waters are used by sea turtles? (Chapter 3)*

Understanding threats:

3. *Can the extent of illegal take and use sea turtles be quantified, and where is this take most likely to occur? (Chapter 4)*
4. *What are the main drivers and motives for illegal take and use of sea turtles? (Chapter 5)*
5. *What are the main threats to Mozambican sea turtles? (Chapter 6)*

Conservation & Management- gaps and challenges:

6. *What are the main limitations to conservation and management efforts? (Chapter 6)*

Box 7.1. Five main research questions of this thesis.

Review of findings

Citizen science and photo-ID for monitoring in-water turtle populations

Chapters 2 and 3 explore the use of citizen science and photo-ID as tools to facilitate the collection of data on turtles encountered in- water. The principle findings from these chapters suggested that citizen science can be a robust tool for collecting basic biological baseline data. Such datasets, coupled with photo-ID, certainly strengthened the data quality collected by citizen scientists. Both, individual green and loggerhead sea turtles could be successfully identified and re-identified at the study site from unique facial scute patterns examined from photo-encounter data collected by citizen scientists and local researchers. I found TORSOOI a valuable tool for facilitating photo-ID and would recommend the continued use of this online database and semi-automated photo-ID tool for sustaining and expanding in-water monitoring of sea turtles using citizen scientists. The TORSOOI system could be improved in two ways, 1) if the encounters from the dive log could be linked to the Photo-ID encounters, to minimise repetitive data entry, 2) the ability to have an offline data entry function that syncs the record when the internet connection is reliable, rather than relying on a fast and live connection to make an encounter submission. While the quality of dive log records was improved by having a few key, well trained and consistent contributors, the photo-ID database benefitted from the broadened use of public involvement. Results from the GLM on the dive logs (Chapter 3) suggested that sightings and abundance of turtles were influenced by environmental conditions of the dive. Such factors as visibility and diving depth lead to availability and perception bias in the citizen scientists' records to detect sea turtles, rather than reflect environmental or behavioural predictors that influence sea turtles. Future efforts using citizen scientists for monitoring turtles in-water should further investigate availability and perception bias to correct for these (Pollock et al., 2006). Overall, citizen science coupled with photo-ID datasets provided Mozambique with the first details about its foraging sea turtle populations. The low cost nature of these techniques, especially when coupled with semi-automatic photo processing, make such projects attractive, so that their future use and development should be encouraged within Mozambique. These techniques could also be adopted in other developing countries especially those with dive-based tourism, to enable the establishment and maintenance of consistent and long-term baseline monitoring programs. If driven or led by local communities and the ecotourism industry, these projects are more likely to succeed rather than being reliant on government actions and funding.

In-water sea turtle population structure

In chapter 3, I described the first detailed accounts of the use of coastal reefs by green and loggerhead sea turtles in Mozambique. Based on population models from the photo-ID dataset, both green and loggerhead populations were likely to be small yet present year-round. Loggerhead sea turtles of sub-adult or adult size classes were the dominant species on reef systems. However, these animals appeared to have short term residency (246 days) and be highly transient, moving into and out of the area. In contrast, I report a large range in the size class of green turtles (50 cm – 120 cm). Evidence of variation in behaviour between different age and sized green turtles indicated differences in the way they use the area. Individual juvenile green turtles exhibited a high degree of fidelity to particular shallow (<16 m), nearshore- reefs, and demonstrated significantly longer residency periods (>1000 days) than loggerheads (~500 days). Resightings of individual photo-ID green turtles were more frequent in juvenile greens, suggesting sub-adult or adult sized animals may be more transient to the area. Population models of both species were limited by sample size, so that their results should be interpreted as indicative rather than conclusive. These population models should be rerun as more photo-ID data become available. While both hawksbill and leatherback turtles were reported through the dive log and photo-ID encounter datasets, their encounter rates were too low for analysis. It is likely that both of these species are vagrants to the area, however further investigation into seasonality of their occurrence would be useful. Regardless of species, sea turtles favoured coastal nearshore waters and relatively shallow reef systems which make them particularly vulnerable to interaction with small scale fisheries. Impacts of SSF on sea turtles using coastal reefs are unlikely to be consistent among species or age-classes. My findings suggest that the long term residency of late stage juvenile greens in these nearshore and shallow habitats make them most vulnerable to interactions with SSF.

Illegal take and SSF: a prominent threat to sea turtles

Based on the findings of Chapter 4, illegal take of sea turtles occurs year-round and is widespread throughout Mozambique. Similarly, illegal use of sea turtles, primarily for meat was common, and it was rare to detect more than an empty carapace or old bones. Even stranded sick or dead animals, sea turtles and dolphins were illegally collected for illegal use (personal observation). Transect sampling in the sand dunes demonstrated that the Tofo area and greater Inhambane peninsula are hotspots for illegal take of sea turtles. SSF interact with turtles in their favoured habitats (close to reefs systems) of near coastal inshore waters, particularly in the south, between Praia do Tofinho and Praia de Rocha (Refer to Fig.4.7 for map). SSF interaction did not occur in northern or southern extents of the study area, in plate or soft coral habitats (which showed higher turtle SPUE (Chapter 3)), suggesting some refuge habitat is available for sea turtles. Based on interviews with fishers, the opportunistic take of turtles is prevalent and widespread (Chapter 5). The existence of a targeted marine megafauna multi-species fisheries, suggest that the widespread use of gillnets and long-line fishing gear are favoured because their non-selectivity promote the capture of turtles and other species. In these fisheries, turtle capture is not bycatch or accidental.

Socio-economic factors influencing artisanal fishers take of turtles

Interviews with fishers (Chapter 5) demonstrated variability in the motives and drivers influencing fishers to illegally take turtles, with variability among communities and individuals. In the two fishing communities surveyed, opportunities for alternative livelihoods were lacking or insufficient to supplement their reliance on fishing activities. Five of the six major drivers identified in Chapter 5 reflect Mozambique's low socio-economic status and high human development (HDI 180/188) index scores. Similarities were evident between the drivers and motives of illegal take of turtles and the terrestrial mammal bushmeat hunting and trade. The majority of fishers, from either community had multiple motives for participating in illegal take of sea turtles. Pressure on the marine environment is increasing, resulting from coastal population growth and expanding SSF, even while marine productivity is decreasing and most coastal fisheries are thought to already be overexploited. It is concerning that low stability in governance and a declining economy may increase rates of illegal take of sea turtles, as well as and exacerbate the bushmeat trade.

Recently, Madagascar and the Philippines have reported a growing black market for sea turtle products and noted the presence of overseas buyers (Humber et al., 2014; Poonian et al., 2016; see IOSEA 2014 for review of illegal sea turtle trade in the Indian Ocean). While this has not been conclusively proven within Inhambane Province, anecdotal evidence suggests it occurs. Products made from sea turtle carapaces are widely sold throughout Mozambique in touristic and craft markets (Louro et al., 2006). Although not yet a prominent issue within Mozambique, differentiating between take for indigenous or subsistence harvest and illegal commercial exploitation is becoming an increasing challenge within other parts of the SWIO region and beyond (Humber et al., 2014; Poonian et al., 2016). Since the civil war, illegal wildlife trade has become an emergent issue within Mozambique (Lindsey et al., 2013). Exacerbated in recent years (e.g. exponential growth in illegal killing of rhinos between 2007-2013; Minin et al., 2015), Mozambique has quickly become a known hotspot for the illegal wildlife trade (IWT) in both marine (sea horse, sea cucumber, shark fin (Pierce et al., 2008)) and terrestrial species (Rhino, elephant, lion, pangolin (Lindsey et al., 2013)). Given that network and trade pathways are already well established, it is easy to imagine how the illegal take of sea turtles by artisanal fishers for local domestic uses could quickly escalate into an emergent aspect of IWT.

Conservation and management efforts- experts

Consensus of expert opinions revealed the most pressing threats to sea turtles were fisheries related (bycatch from commercial trawling, small scale fisheries bycatch and hunting of nesting turtles). The top ranking threat, (commercial bycatch of the shallow water prawn trawl industry) could easily be mitigated with effective implementation of pre-existing TED's

(Turtle Exclusion Devices) policy. This is unlike the other two threats that are likely to be dependent on extensive changes and improvements to living standards and Mozambique's overall socio-economic status. Compliance with sea turtle legislation was weak throughout the country. Experts identified improving enforcement efforts as critical to improving conservation of sea turtles. However, improving enforcement capacity (or its effectiveness) is only one tool for increasing compliance. Exploring alternative methods such as persuasive communication for increasing voluntary compliance, would also be highly beneficial (Arias 2016). Parallels are evident between the issues that hamper the conservation and management of terrestrial megafauna and marine megafauna. This suggests that, in order to address some of these conservation management issues (Chapter 6), a holistic process will be required to solve large-scale issues (e.g. governance, corruption, compliance) and strengthen overall biodiversity conservation.

It is likely that improved stakeholder collaboration and clearly defined roles and responsibilities of stakeholders would strengthen institutional capacity. A sea turtle conservation action and management plan would be highly beneficial to clarify necessary steps, roles and data gaps to progress management efforts. Given the extremely limited funding allocated to the conservation of sea turtles and the marine environment and limited access to skilled people and resources, a prioritised list of management actions for sea turtle hotspot areas is necessary, although challenging to develop given the different ways people value turtles and their habitats. Ideally, a list of conservation actions should include addressing known data gaps, identifying further hotspots and detailing specific actions for each area. Collated into a plan, the actions need to be truly representative of the critical tasks needed to progress conservation management and to focus on a small subset of shared goals between negotiating stakeholders.

Strong similarities are evident between the identified threats, gaps and constraints to conservation and management of lions (*Panthera leo*), and of those relevant to sea turtles. A conservation strategy and action plan for lions documented issues under the main themes of management, politics, socio-economics, policy, and land-use and trade (Fusari et al., 2010). Many of these issues have been identified throughout my thesis, particular Chapter 6. The lion strategy and action plan could provide a useful template for the preparation of a sea turtle focused plan.

Awareness of turtle protection laws among fishers was high, suggesting that campaigns to increase awareness of turtle legislation will have little impact in deterring illegal take. Future conservation efforts need to respect the different values of people, address food security, livelihood options, and aim to reduce or change the number of motives an individual fisher or community may have to participate in illegal take. Introduction of alternative livelihoods and ecotourism are examples of ‘conservation by distraction’, which aim to draw people’s attention away from actions that are environmentally unsustainable (Ferraro and Hanauer 2014; Wunder 2000). Both approaches need to be carefully designed and implemented to prevent unintended or negative outcomes to local communities or the environment. This however, is not an easy task, because people and communities often have different reasons for valuing turtles and other natural resources (Arias 2016). Thus, further socio-economic research is required in coastal communities to explore their willingness to consider and adopt alternative livelihoods and other marine conservation initiatives. It is clear that coastal people place different values (c.f. the developed world’s conservation values) on the resources- animals, plants and habitats. It is fundamental that local communities trust the initiatives and are able to see clear and tangible benefits, such as ecotourism and conservation of wildlife, in order to support and adopt such changes to livelihoods. While a few examples of sustainable (environmental or social) ecotourism exist in Mozambique, the majority of tourism enterprises are developed by expatriates and rely heavily on imported products, while local communities do not see the direct financial benefits of such undertakings (Tibiriçá et al., 2011).

Management considerations implications

Management of a flagship marine species

Given the broad threats to sea turtles in Mozambican waters, management efforts should (among other direct management actions) aim to achieve consistent baseline monitoring for sea turtle populations throughout the country, both within and outside of MPA areas. Conservation and management efforts need to be guided using baseline knowledge of biology and threats, such as those documented in this thesis. Baseline population monitoring currently primarily occurs in the country's most significant nesting area, in the southern trans-frontier conservation area. Continuation of this program is critical, especially given it is the most effective MPA area in the country for compliance with turtle protection legislation and fisheries regulations. However, the potential impacts of threats need to be considered in relation to the size of the overall turtle population it affects. The green and loggerhead turtles impacted by threats in Mozambique likely come from other large stocks spread throughout the SWIO. Therefore, monitoring of both these species in the broader SWIO is essential.

Putting aside the financial or logistical challenges, achieving effective population monitoring on the spatial and temporal scales required to effectively detect changes in abundance, in either Mozambique or the SWIO region, is likely to be difficult, essentially because of either the remote locations, access to resources or the low density of nesting spread across large areas. Consideration of a rapid assessment style aerial surveys, which could be easily replicated and increase knowledge of spatio-temporal patterns of turtles (i.e. seasonal variations in abundance, distribution) and identify important habitats. Aerial surveys (by drones), may present a better opportunity to achieve baseline population monitoring along large expanses of low density nesting beaches, than relying on foot or car patrols to evaluate population trends. Opportunities to combine such technologies and survey efforts with the monitoring of other marine megafauna populations should be sought.

Uncertainties in the relative abundance of sea turtles using Mozambican waters and a lack of robust information on the numbers of animals (and size classes) killed by SSF, make it difficult to conclude whether the current level of removal (illegal take) for any of the five sea turtle species is sustainable or not. Emerging threats within Mozambican waters and throughout the SWIO region include illegal unregulated and unreported fishing (IUU), IWT and largescale industrial developments in northern Mozambique. The scale of these threats, and their impacts are unknown and are generally extremely data deficient. Management efforts will need to focus on promptly addressing these deficiencies.

In order to achieve effective conservation and management, multiple actions (monitoring and management) that focus on the most important (or demographically sensitive) age classes of turtles are required (Fuentes et al., 2015). Therefore, an improved understanding of the most important age class(es) per species occurring is the SWIO to sustain populations will be necessary (Donlan et al., 2010). In addition, enhanced understanding of the ontogenetic patterns of each species is needed. Given that regional differences in life history strategies occur, it is possible that each species may need a customised suite of priority actions. Effective conservation management efforts will need to occur simultaneously and at multiple scales based on movements of animals. Satellite and or acoustic tagging will be essential to achieve this. Finally, a range of conservation management actions from localised to provincial and national scales are needed, all of which require coordinated efforts through various jurisdictions (provincial, national or international).

Legislation, compliance and corruption

Non-compliance in a conservation context is very common across the globe (Arias 2015). I found it to be high amongst small scale fishers. In addition to non-compliance, fishers attributed or regarded officials to be easily corruptible. Corruption may involve an official directly in a wildlife crime and/or omission of duty whereby officials allow misconduct (e.g. accepting bribes or ignoring fishing violations (Gore et al., 2013).
Findings presented in this thesis suggest non-compliance with sea turtle protection laws is common throughout Mozambique, particularly at the case-study site in Tofo and along the Inhambane Peninsula. Similarly, inaction and corruption by officials were also commonly reported by fishers (Chapter 5). An enhanced understanding of the factors that lead small scale fishers into non-compliance with turtle regulations would be valuable, with the ultimate goal of using such knowledge to achieve compliance

more effectively. Low capacity, limited resources, low motivation, high levels of corruption and weak governance are all likely to contribute to the difficulties Mozambique experiences in effectively achieving regulation of its environmental policies (marine or terrestrial).
Rule compliance is necessary for successful conservation (Kahler and Gore 2012). Reducing the negative effects of corruption on conservation will be key to success (Gore et al., 2013). Improvements in these two areas, (i.e. compliance and corruption) will be necessary for successful conservation efforts within Mozambique. Chapter 6 highlights the problems faced due to the absence of a clear division of responsibilities between various government agencies, which has also been highlighted as a significant issue influencing the lack of management action to address the emerging issues of marine bushmeat (CMS 2016b).

Patrolling and enforcement efforts are weak due to a limited capacity to control human activities at the scales necessary to be effective over the entire Mozambican coastline, or even within the expanse of the five MPA's. It is currently (and will remain) a challenge for local authorities to find effective ways to enforce environmental laws in Mozambique, and it is likely that actions implemented will need to vary among coastal provinces to ensure maximum effectiveness and address local issues. Regardless of which techniques are trialled or adopted, securing sufficient funding and staffing to ensure existing laws are enforced will be critical. Finally, given that most of the fishers I surveyed in my study already possessed awareness and understanding of the existing turtle protection laws, government management actions will need to focus on achieving compliance, rather than an awareness campaign for promoting laws.

The Mozambican government appears to find achieving effective and comprehensive enforcement of legislation relevant to its marine and coastal ecosystems or protected species (i.e. sea turtles and dugong) challenging (Pereira et al., 2014b). Illegal take was reported in all five marine protected areas (Chapter 4). This finding is not unexpected, as many of the countries within the SWIO struggle to effectively patrol their coastal areas and enforce legislation to protect their marine species (e.g. Madagascar, Tanzania, Kenya (Muir 2005; Okemwa et al., 2004; IOSEA 2014; Humber et al., 2015). Several reasons relevant to Mozambique have been postulated to explain lack of enforcement efforts; 1) expansiveness of coastline, 2) lack of capacity for implementation, 3) reluctance to manage a fishery with strong cultural links (Rakotonirina and Cooke 1994; Okemwa et al., 2004; Okemwa et al., 2005; Humber et al., 2011). Mozambique has many offshore islands which are likely to host nesting and foraging turtles, and restricted access to these islands inhibits effective law enforcement, a problem also noted in the Philippines (Poonian et al., 2016). A focus on community outreach and education programs are needed, particularly within villages and communities proximity to high density SSF areas that overlap with turtle migratory corridors, or foraging and nesting grounds. Discussing biology and conservation with local communities is important (Poonian et al., 2016). The aspect of delayed consequences from overexploitation of a long-lived species is particularly important. I experienced this after outreach talks at Dovela, where subsequent positive collaborations have been made to locally monitor and report turtle activity (nesting, fishing, stranding) (JL Williams pers. obs. 2016; see blog article in appendix). Conservation and management efforts that integrate with communities may be able use local traditional knowledge to compliment scientific data or fill data gaps (i.e. Sofala and Zambezia provinces) (Poonian et al., 2016).

Community based management (CBM)

Top-down, government-led enforcement is only one tool for management of sea turtles, with an alternative being community based management (CBM). Local scale conservation efforts that could be focused on hotspot areas (either biological or anthropogenic) may be used to supplement top-down style management. Particularly outside of MPA or in remote areas, which would essentially be beyond the reach of effective management lead by provincial or local authorities. CBM may provide increased understanding of seasonality of animals and seasonality of threats by using local community ecological knowledge.

Along the Mozambican coast, the culture of coastal communities is thought to vary significantly. Further effort needs to be dedicated to document and understand fundamental cultural values and how they differ from south to north, as it is likely to be a major factor influencing conservation and management efforts (e.g. compliance, interest in CBM, resource use patterns) of natural resources. In areas with strong cultural values, communities should be consulted about their desire to participate in CBM prior to co-management arrangements being drawn up. Some terrestrial and marine CBM areas already exist within Mozambique. In Vamizi Island, in the Quirimbas Archipelago, of Cabo Delgado province, two local CCP's (Conselho Comunitário de Pesca: Community Council of Fishers) were established and empowered legally to manage their resources and implement fishing regulations within 3 nautical miles of the coastline (Garnier et al., 2012). The CCP's were government- supported, and capacity building efforts were led by a local conservation organization on the island. Through an environmental awareness campaign, the CCP's decided that a sanctuary area should be established to protect critical feeding and breeding areas for sea turtles and reef fish (Garnier et al., 2012). The CBM in Vamizi is thought to have led to a significant reduction in the slaughter of nesting turtles, and also oversees management of gillnets in their coastal waters (Garnier et al., 2012). The main risk to turtles in coastal waters appears to be targeted hunting, gill netting, long- line fishing and interactions with other SSF gear. It is probable that increasing pressures resulting from SSF are likely to rise, driven by the poor performance of the national economy. An increasing frequency of climate-related pressures (e.g. drought, flood, storms and cyclones) is likely to further exacerbate the reliance coastal communities have on the marine environment, especially if community based agricultural efforts are impacted. With this in mind, throughout Mozambican waters, further investigation is required to evaluate if CBM approaches can address the emergent threat of turtle gillnetting. An alternative livelihoods program now occurs at Vamizi, which is also thought to have strongly influenced the success of the sanctuary area and overall compliance with environmental regulations in that local community. Such strategies (e.g. CBM) need to be complemented by broader government conservation measures to protect sea turtle populations against other major threats such as commercial fisheries impacts, IUU, IWT and industrial exploration and development.

CBM is likely to be more successful in some sites than others, and trial periods and extensive community consultation will be required. One approach to trial certain areas or communities in CBM could be to involve local communities in establishing a sea turtle stranding network. The network would encourage information sharing on strandings and mortalities and potentially provide insight into illegal take and use. Such a scheme is logistically possible and has been used in Baja California (Peckham et al., 2007), and may be more acceptable than involving communities in direct monitoring of sea turtle mortality (given the illicit nature and pressure to not report peers). A stranding network would have the added benefit of increasing general understanding of sea turtle demography, and the biology of turtles and other marine megafauna. Through engagement and interaction in a stranding network, suitable and interested communities could be selected to advance CBM and alternative livelihood projects.

Future Research

Future research efforts into the following areas would be highly beneficial for advancing baseline knowledge of Mozambican turtles and their threats;

- Identifying and mapping important foraging and developmental areas are necessary to examine overlap between threats and important habitats or aggregations.
- Determining fine scale on spatial ecology- movement heterogeneity and home range of foraging turtles (either satellite or acoustic tagging utilising existing acoustic receiver network) is necessary to identify home range, foraging ecology and rates of exposure to threats.
- Identify turtle-fisher interaction hotspots (e.g. Inhassoro or Tofinho-Praia de Rocha) for trialling a capture and release program with fishers is necessary to examine catch rates, retention rates and collect data on species identification.
- Genetic stock analysis (tissue and bone) is necessary to understand the full implications of illegal take and to determine which RMU’s are most affected by illegal take in Mozambique. This would need to be coordinated with other similar projects elsewhere within the western Indian Ocean.

- Research on socio-economic factors relevant to SSF in the central and northern provinces, including culture and tradition of turtle fishing from these areas are needed to understand the costs, benefits and barriers to any mitigation.
- Quantify for each species the rates of decomposition of carcasses discarded in the sand dunes to guide age of remains detected during mortality surveys and enable more robust estimates of turtle mortality.
- Expansion of the citizen science program, particularly submissions of photo-ID encounters to enable inter-connectivity between provincial areas within Mozambique and regional scale movements through the SWIO. This would need to be coordinated with other similar projects within the western Indian Ocean. This could also include studies to look at the possible effect of boats and divers on turtles and the continued expansion of the laser photogrammetry dataset to facilitate accurate measurement of turtles and investigate growth rates.
- Collaborate with other countries and international agencies (e.g. WIOMSA or IOSEA) to understand the population size and status of the SWIO green turtle and loggerhead turtle stocks

Concluding remarks

Conservation and management efforts for sea turtles (and many other fauna) in Mozambique is hampered by lack of scientific information. My research tackled this by establishing and increasing the baseline (species composition, population structure, residency, threats and socio-economic factors driving illegal take and use). Future focus is needed to improve spatio-temporal ecology and habitat use of sea turtles in Mozambican waters, factors influencing compliance of SSF with sea turtle legislations and detailed assessment of SSF dynamics. Continued monitoring programs using citizen science for in-water monitoring are strongly encouraged. Continued monitoring of illegal take and use of sea turtles throughout Mozambique is critical. On-ground, capacity building (of enforcement and government agencies, tourism stakeholders and local communities) will be critical to improve all aspects of conservation and management of sea turtles.

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Overview of Appendices

Appendix 1: Chapter 2 citizen science supplementary materials

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2. Research dive log form
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Appendix 2: Chapter 3- in-water ecology supplementary materials

1. Fig. S2.1. Example of Photo-ID resighting records from one individual showing left and right profiles.
2. Fig. S2.2. Examples of photo quality and variation in submissions. Combinations of high angle or low clarity (not both) could be used to determine individual scute patterning with the TORSOOI semi-automated system.
3. Fig. S2.3. Scientific poster based on Chapter 3 presented at the 35th International Sea Turtle Symposium, 19-24th April 2015, Dalaman, Turkey.

Appendix 3: Chapter 5- Motives and drivers for illegal take and use

1. Questionnaire for small scale fishers.
2. Tradition of take. Sea turtle consumption in Dovela, Mozambique. Article written based on results from Chapter 5.
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Appendix 4: Chapter 6- Perception of threats

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Appendix 1

(Chapter 2- Citizen Science)

1.1 In-Water Marine Turtle Sightings (Mozambique)

To keep a record of any turtle activity encountered on a dive or sighted on an ocean safari

*Required

Date (dd/mm/yyyy) *

Time (in 24 hr clock) *

Location/ Dive Site *

- Salon
- Office/ Oasis
- Manta
- Outback/ Hogwarts/ Kingfisher
- Giants Castle/ Galleria
- Clownfish
- Mikes Cupboard/ Croc Rock
- Sherwood Forest
- Amphitheatre/ Chamber of Secrets
- Table Top
- Chimney/ Simons Town
- Praia de Rocha
- Amazon
- Marble Arch
- Two Mile Reef
- Coral Gardens
- Pestana House Reef/ Manta Reef
- LJ13
- Pinhos Point
- Witches Hat, Zavora
- Inhaca Marine Reserve Snorkel area
- Other:

GPS (South)

e.g. -23.xxxxxx

GPS (East)

e.g. 35.xxxxxx

Turtle presence/absence *

Were sea turtles present on this dive?

- o Yes
- o No

How many turtles in total were present? *
Please type a number only. 0, 1, 2, 3, 4.......

Species *

- o Green (4 separate scutes)
- o Hawksbill (4 overlapping scutes)
- o Loggerhead (5 separate scutes)
- o Leatherback (leathery shell, longitudinal ridges)
- o Olive Ridley (5 or more separate scutes)
- o Species not confirmed

Size (m) *
Size estimate is taken from the tip of the shell behind the turtles neck to the end of the shell above the tail.

Size *

Size estimate is taken from the tip of the shell behind the turtles neck to the end of the shell above the tail.

- o Laser measured
- o Visual estimation

Sex *
Sex can only be determined in large animals > 1m, by looking at the length of the tail. Very long tails indicate males

- o ~ 1 m turtle with long tail (>10 cm)
- o ~1 m turtle with short tail (<10 cm)
- o Large turtle but could not see tail
- o small / juvenile turtle

Health *
- o Does turtle have signs of recent injury?
- o Does turtle have signs of old injury?
- o Does turtle show signs of illness?

- Turtle showed none of these indicators
- I did not assess health/ could not see

Injury comments

If injured or ill, explain what the injury was, where on the turtle, did it effect swimming behaviour, was it old or new injury?

Behaviour *

What was the turtle doing, when it was encountered?

- Resting/ Sleeping
- Feeding
- Swimming
- Surfacing
- Other:

Habitat *

Where was the turtle observed?

- Seagrass/ Macroalgal beds
- Rocky reef
- Sandy
- Water column
- Surface

Sea State *

Based on Beaufort scale (takes into account the swell and winds)

- 0= Calm, 0m, flat
- 1= Light air, 0 - 0.2m, swell, ripples without crests
- 2= Light breeze, 0.2- 0.5m, small wavelets, crests with glassy appearance
- 3= Gentle breeze, 0.5-1m, large wavelets, crests begin to break, scattered whitecaps
- 4= Moderate breeze, 1-2m, small waves, breaking crests, fairly frequent whitecaps
- 5= Fresh breeze, 2-3m, moderate waves, many whitecaps, some spray

Visibility (m) *

in meters

Water temperature (°C) *

degrees Celsius

Depth (m) *

What depth was the turtle encountered?

Encounter duration (min) *

How long were you with the turtle?

Avoidance to Divers/ Boat *

Did the animal show any avoidance to divers in the water or the Boat?

- Yes
- No

Number of divers in water *

ID Photos taken (Please email photos to moz.turtles@gmail.com) *

ID photos need to be left or right close ups of the face, showing scales behind the eye, and of the whole turtle shell from above.

- Yes
- No

Photo Left of face *

- Yes
- No

Photo Right of face *

- Yes
- No

Photo of carapace (Shell) from above *

- Yes
- No

Dive Centre

Recorded By *

Email contact

Additional comments

Describe strange behaviour, unusual markings which may be used to assist in photo-ID or any other interesting details

1.2 Research dive log form

To keep a comprehensive presence/absence record of all megafauna species on dives.

Dive site

- buddies
- clownfish
- salon
- mikes cupboard/croc rock
- office/oasis
- giants castle/galleria
- amazon
- hospital
- outback/hogwarts/kingfisher
- marble arch
- chimney/Simons town
- manta
- sherwood forest
- 2 mile
- white sands
- 3rd pinnacle
- beluba reef
- anchor bay
- red sands
- arcadia
- playstation
- camel humps
- Ampitheatre/chamber of secrets
- Other:

Time in (24hr clock)
Time out (24hr clock)

Bottom Time

(minutes)

Sea state (beaufort scale)

Based on Beaufort scale (takes into account the swell and winds)

- 0= Calm, 0m, flat
- 1= Light air, 0 - 0.2m, swell, ripples without crests

- 2= Light breeze, 0.2- 0.5m, small wavelets, crests with glassy appearance
- 3= Gentle breeze, 0.5-1m, large wavelets, crests begin to break, scattered whitecaps
- 4= Moderate breeze, 1-2m, small waves, breaking crests, fairly frequent whitecaps
- 5= Strong breeze, 2-3m, moderate waves, many whitecaps, some spray

Underwater visibility horizontal (m)

Water temperature (°C) - surface

Water temperature (°C) - at depth

Maximum depth (m)

Surge/current (direction & strength)

Please check two answers

- North to south
- South to north
- negligible
- moderate
- strong

Turtle sighted?

- yes
- no

Species

- Green (4 separate scoots)
- Hawksbill (4 overlapping scoots)
- Loggerhead (5 separate scoots)
- Leatherback (leathery shell, longitudinal ridges)
- Olive Ridley (5 or more separate scoots)
- Species not confirmed

Sex

Sex can only be determined in large animals > 1m, by looking at the length of the tail. Very long tails indicate males

- Adult male
- Adult female
- Adult - sex not confirmed

- Juvenile - sex not confirmed
- Sex not confirmed

Size Estimated carapace length(cm)

Measured (laser photogrammetry) carapace length (cm)

Health

- Healthy
- Unhealthy
- Inactive/Could not determine

Behaviour

What was the turtle doing when it was encountered?

- Resting/sleeping
- Swimming
- Surfacing
- Feeding
- Other:

Habitat

Where was the turtle when it was encountered?

- Seagrass bed
- Rocky reef
- Sandy area
- Water column
- Other:

Encounter duration (min)

How long were you with the turtle?

Avoidance to Divers/ Boat?

- yes
- no

Number of divers in water

ID Photos taken (Please email photos to moz.turtles@gmail.com)

- yes

- no

Photo Left of face

- yes
- no

Photo Right of face

- yes
- no

Photo of carapace (Shell) from above

- yes
- no

Additional comments

Describe strange behaviour, unusual markings which may be used to assist in photo-ID or any other interesting details

Other megafauna sighted

Was any other megafauna sighted on the same dive?

- yes
- no

If yes, which animals were present?

- Giant manta ray
- Reef manta ray
- Mobula ray
- Small eye stingray
- White tip reef shark
- Whale Shark
- Leopard shark
- Grey reef shark
- Black tip reef shark
- Bowmouth guitar shark
- Bottlenose dolphin
- Humpback dolphin
- Humpback whale
- Dugong
- Other:

Comments on other sightings of megafauna

Describe strange behaviour, unusual markings which may be used to assist in photo-ID or any other interesting details

Did you get an ID shot of any other megafauna?

- yes
- no

Recorded by:
Email contact:

Date (dd/mm/yyyy).

1.3 Scientific poster based on Chapter 2.

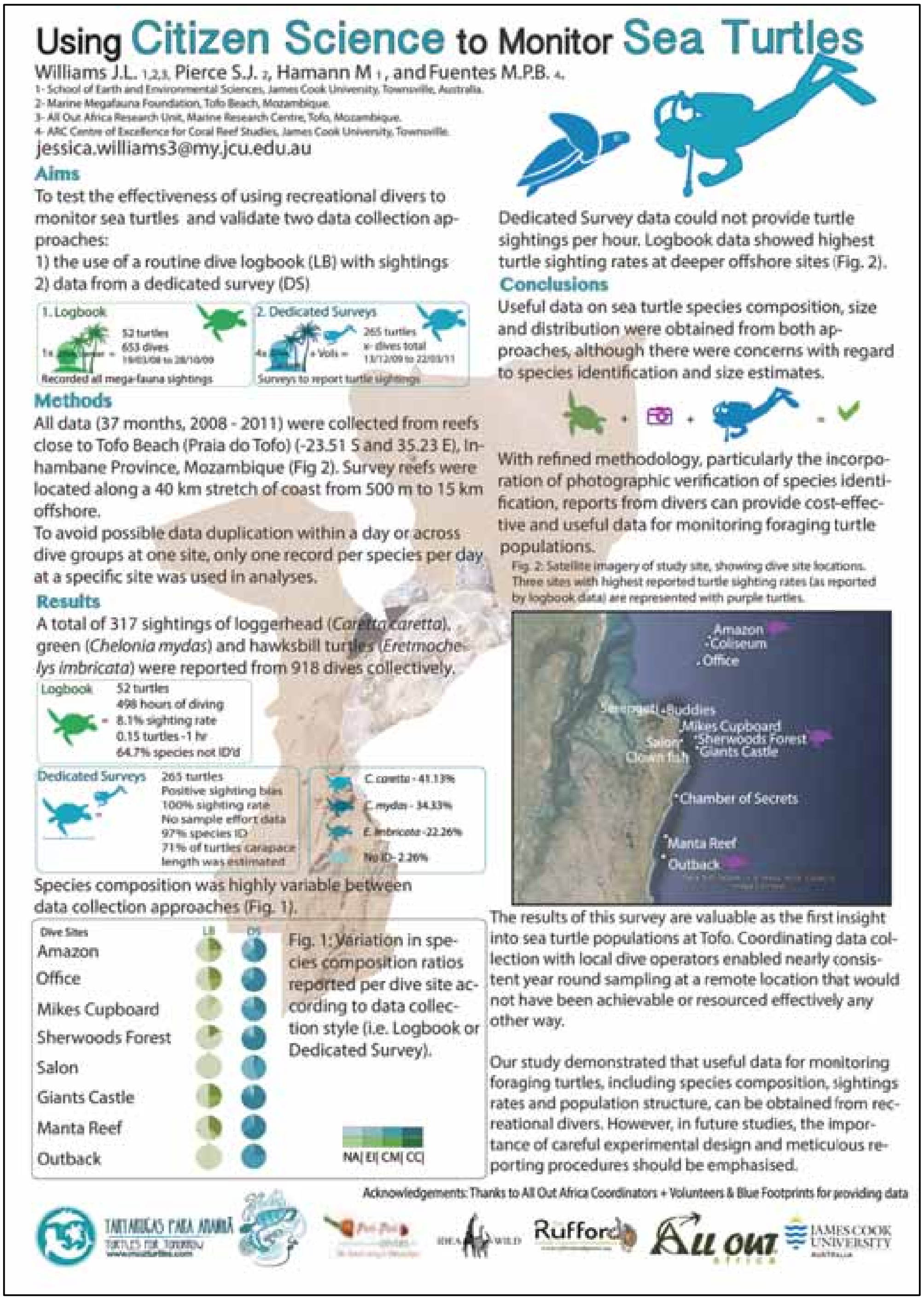

Fig. S1.1. Scientific poster based on Chapter 2 presented at the Western Indian Ocean Marine Science Association Biennial Symposium 8. 28th Oct – 2nd Nov 2013, Maputo, Mozambique.

Appendix 2

(Chapter 3- In-water ecology)

2.1 Photo ID supplementary materials

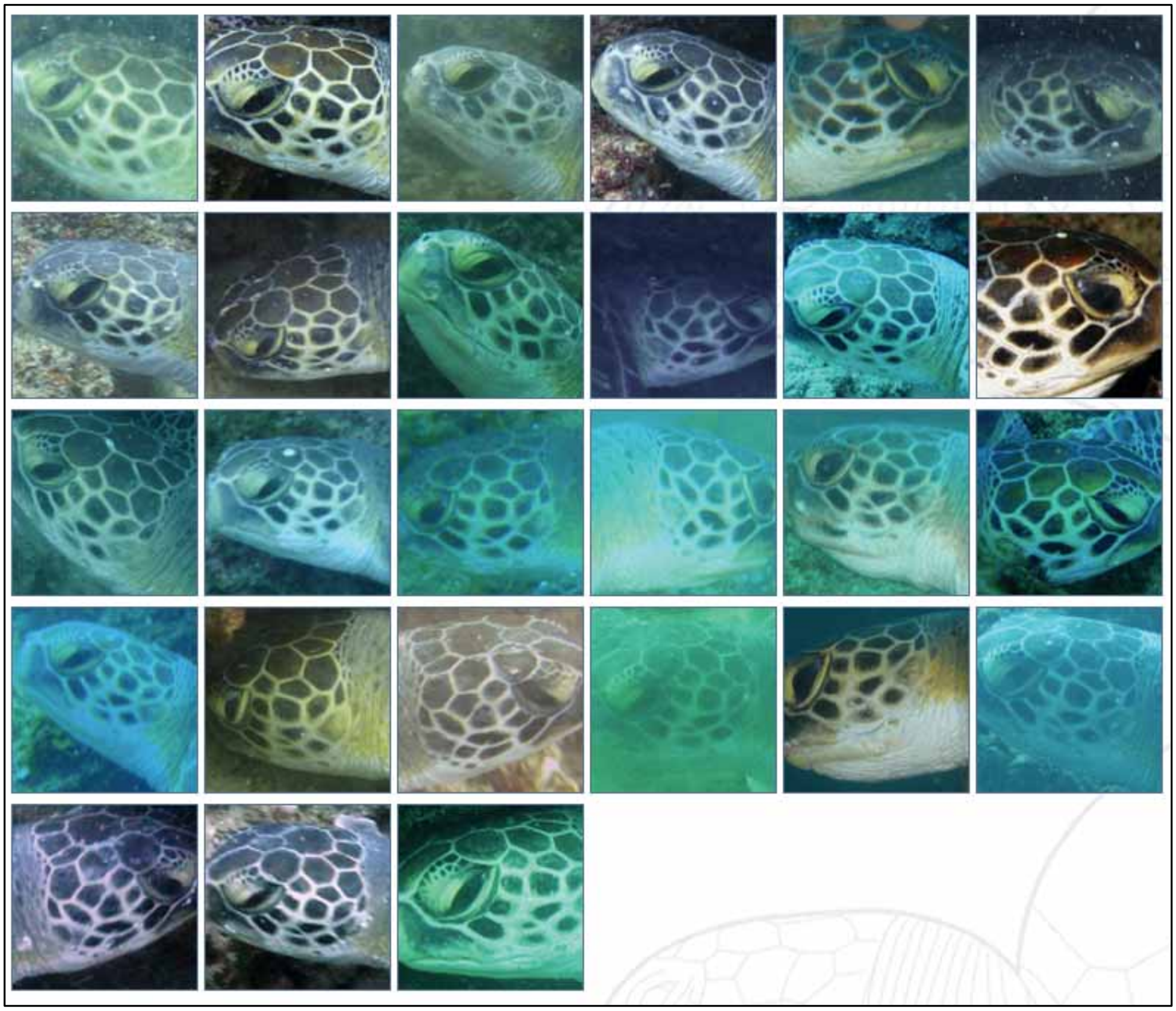

Fig. S2.1. Example of Photo-ID resighting records from one individual showing left and right profiles.

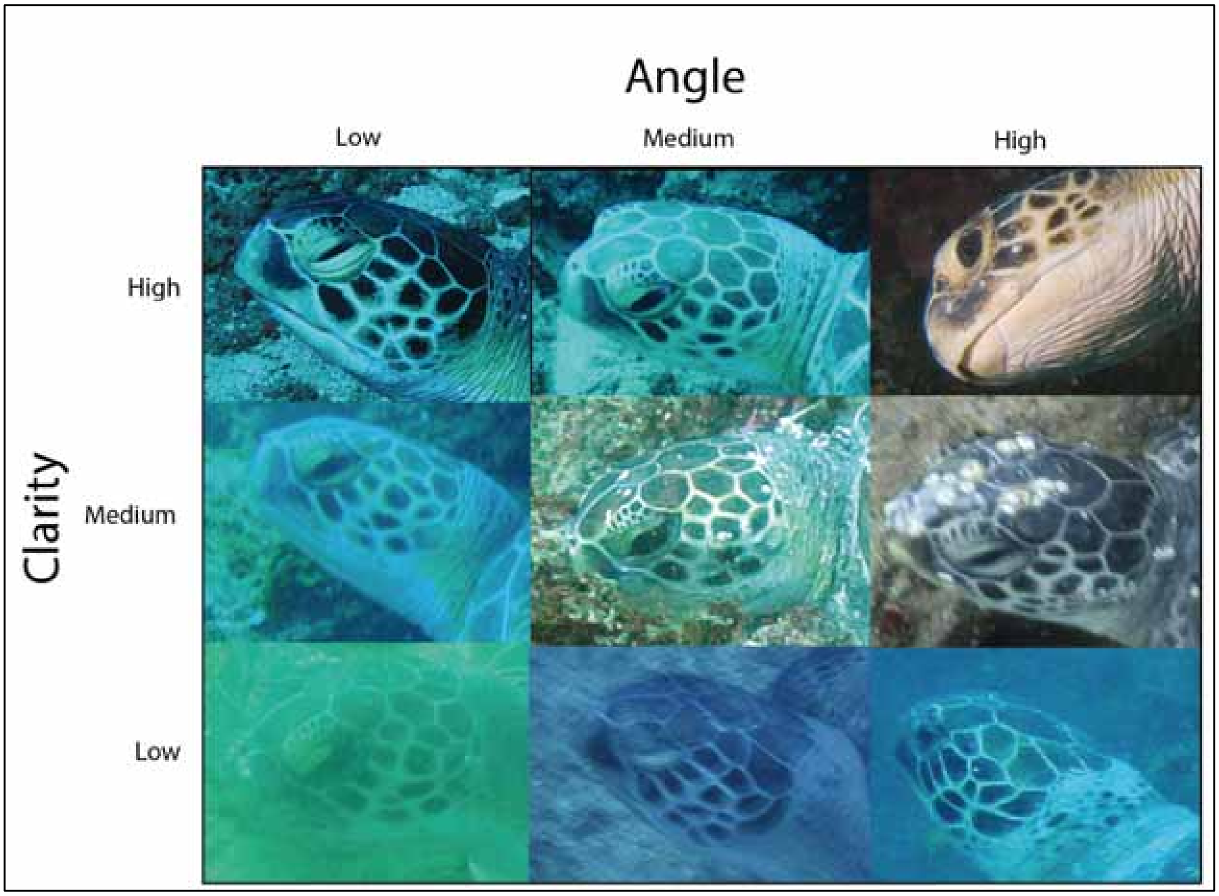

Fig S2.2. Examples of photo quality and variation in submissions. Combinations of high angle or low clarity (not both) could be used to determine individual scute patterning with the TORSOOI semi-automated system.

2.2 Scientific poster based on Chapter 3

First results from Mozambique:

Sea turtle population demographics

Williams J.L. [1,2,3] Pierce S.J. [2] Fuentes M.P.B. [4] Hamann M [1]

1- College of Marine and Environmental Sciences, James Cook University, Townsville, Australia
2- MarineMegafauna Foundation, Tofo Beach, Mozambique
3- All Out Africa Research Unit, Marine Research Centre, Lubombo, Swaziland
4- Earth, Ocean and Atmospheric Science, Florida State University, Tallahassee, FL US

jess@mozturtles.com, mozturtles.com

Aims

To understand population demographics of *Chelonia mydas* and *Caretta caretta* sea turtles in Southern Mozambique using photographic identification.

Methods

- Identification photos where collected through a citizen science dive log reporting system as reported in Williams *et al.* (2015).
- Images were assigned identification based upon protocols reported in Jean *et al.* (2010) using photo-ID system using the TORSOOI database (www.torsooi.org).
- A modified maximum likelihood modelling approach was used to assess lagged identification rate (R_{τ}).
- R_{τ} is the probability of re-identifying these animals over increasing time periods.
- Residency characteristics of each species compared (Fig. 1 & 3).

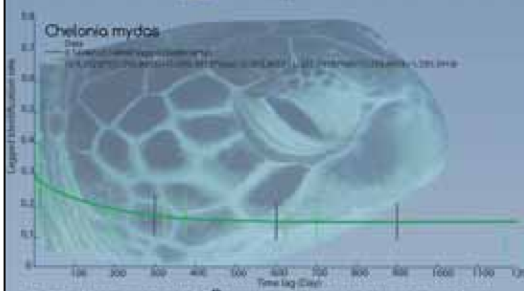

Fig. 1 Best fit population models for R_{τ} generated from resighting information from *C.mydas*.

C. mydas

- 22 indvidual animals identified
- 6 resighted (2 or more times)
- Individuals highly site specific
- Longest time between old-new sighting 1256 days
- Population size estimate (# animals on any given day during study period): 3.35 +/- CI

Fig. 2 Location of study site, Tofo Beach, Inhambane, Southern Mozambique. Dive sites surveyed are marked and dark blue turtle symobls represent *C.mydas* locations and pale symbols for *C.caretta*

Results

Between 2010 and 2014, 840 encounters of four sea turtle species were reported from Inhambane province in Mozambique by recreational divers and researchers (Fig. 2). We assessed photos of facial scutes and carapaces from *C.mydas* (104 submissions) and *C.caretta* (110 submissions) turtles, resulting in the identification of 22 individual *C.mydas* and 39 *C.caretta*.

C.mydas resided in the study area for long periods of time (mean residency time n= 260 days), whereas *C.caretta* were transient (mean residency time 0.8 days).

C. caretta

- 39 individual animals identified
- 6 resighted (2 or more times)
- Animals mostly site specific some inter-site movement is detected
- emigration/mortality model suggests perminent emigration (or poaching?)

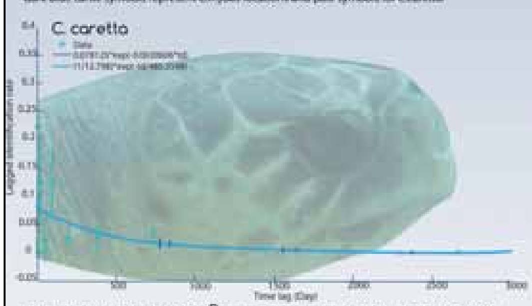

Fig 3. Best fit population models for R_{τ} generated from resighting information from *C.caretta*.

Conclusions

These population estimates and site residency information allow for the impact of poaching on these populations to be assessed and inform conservation and management measures on the ground.

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Williams JL., Pierce S.J., Fuentes M.B.P. & Hamann M (2015) Effectiveness of recreational divers for monitoring sea turtle populations. Endangered Species Research 26: 209-219.

Financial support:
Women Divers Hall of Fame
Rufford Small Grants
International Sea Turtle Symposium
and travel grant sponsors.

Fig S2.3. Scientific poster based on Chapter 3 presented at the 35th International Sea Turtle Symposium, 19-24th April 2015, Dalaman, Turkey

Appendix 3

(Chapter 5- Motives and Drivers for Illegal take and use)

3.1 Questionnaire for small scale fishers

<table>
<tr><td colspan="2">Interviewers name:</td><td>Date:</td><td>Interview number: MZ000</td><td>Age:</td><td>Sex:</td></tr>
<tr><td>Place of birth:</td><td>Community/Village:</td><td>Number of family members to support:</td><td colspan="3">Schooling level:</td></tr>
</table>

Part I – Family economy

1. Economic activities (Jobs):
2. Family income (per month/ day/ season) (minimum required?):
3. Income from illegal fishery (can they tell us amounts per fishery type?):
4. Is fishing a family tradition/business? If so, how many generations have been fishing?
5. Are fishing equipment, techniques or areas where you fish inherited from your family?
6. How long have you been fishing for?
7. Why did you become a fisherman?

Part II – Description of fishery

8. What are the target species that you fish?

9. What equipment do you use to catch these species? (type of boat (size, model, motor), nets (size, material, length) fishing pole and line, spear gun, other equipment?
10. Do you spearfish? If yes- How/ or Where did you obtain the spearfish equipment?
11. Do you fish in a team or alone? Or does it change each day/ season/ depends on type of fishing method
12. If in a team, is there a leader? What is the role of each person?
13. Do all the fishermen come from the same areas/villages?
14. Do the other fishers use other types of fishing methods or have other jobs?
15. Have you ever caught sharks, rays, turtles, mantas?
16. Where is your usual fishing area?
17. *Are there areas where you're not allowed to fish? (Special/traditional or sacred areas, other fishers areas?)*
18. Do you sell you catch? How much does it sell for?
19. How often do you fish?
20. How often does your family eat fish/ seafood/ turtle?
21. How important is the fish/mussels/lagosta/polvo/turtle? you catch as a food source for your family?

Part III- Illegal fishery description and drivers

22. Have you ever caught a sea turtle? If so how did you catch it?
23. How many have caught since you first started fishing?
24. How long have you been catching turtles for? (Since you first became a fisher, not at first, never, only recently)
25. How many sea turtles do you catch per day/week/month/year?
26. Do you sell the turtle meat/shell/eggs? If yes, directly to customers or to a buyer?

27. How much does the sea turtle meat/kg sell for?
28. Which are the main destinations of the turtle meat? To a market or villages on the coast or inland, to a larger town, to Inhambane, to Maputo?
29. How many teams/ fishers work in your area? How many people in total in the region/ Inhambane? Do they all fish for turtle, shark, rays?
30. Is catching turtles harder work than fishing?
31. Is fishing for turtles a planned activity (actively search) or do you only catch turtles if they swim past?
32. Did you know that fishing for turtles is illegal?
33. Are there any other job opportunities?
34. Why do you fish for turtles?

Part IV – Authority

35. Is there any law enforcement in the area? Police/ maritime/ other?
36. How many inspectors did you count?
37. Have you ever been detected/arrested or punished for fishing turtle or any other animals? If so how many times have you been detected/ arrested or punished?
38. Do you know the penalty in case you are arrested?
39. Have you ever avoided being punished or arrested? If so, how (bribes, escaping, etc.)?

Part V – Turtle specific details

40. Do you see turtles in the water when you fish- How many different types of turtle do you see here?
41. Can you differentiate between species?
42. Do you always fish in the same areas? Are there certain places you would go if you wanted to catch a turtle?

43. When you're out fishing how often do you see turtles?
44. Are specific species targeted? Why?
45. Is there a specific size of turtle targeted? Is the biggest turtle best? (Because it has more meat or sells for more money?) Is there a size that's too big? (Too heavy to carry or too hard to catch)?
46. Do you always catch turtles from in water?
47. Have you (or have you seen others) ever caught a nesting turtle on the beach?
48. When did you last see a nesting turtle on the beach? Where was this?
49. Do you dig up the turtles eggs? What for?
50. Have you eaten sea turtle meat, or eggs? If so, when was the last time you consumed turtle?

Part VI- Perceptions of environmental change and motivations

51. Do you catch the same amount of fish, turtles, sharks and rays now compared to when you first became a fisher? If less or more, why do you think that is?
52. How has fishing changed since you first started? (Are there more people fishing? Do you or others use different fishing techniques now to make fishing easier? Do you need to spend more time or less fishing- why is this- bigger family/ more food/money needed- takes longer to catch the same amount?)
53. If you have caught a turtle- What motivated you to fish for turtles?
54. What would motivate you to stop fishing for turtles?
55. Do turtles need protection? If so what are the threats?
56. What is your biggest concern as a fisher for the future?
57. If other jobs were available would you stop fishing?

3.2. The tradition of take: Sea turtle consumption in Dovela, Mozambique.

Article focused on traditions and cultural practices surrounding sea turtle take and use based on interview results from Chapter 5.

The Tradition of Take: Sea Turtle Consumption in Dovela, Mozambique

Jess Williams [1,2,3], Simon Pierce [3], Mariana M.P.B. Fuentes[4] & Mark Hamann[1]

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[2]Tartarugas Para o Amanhã, Tofo, Mozambique.
[3]Marine Megafauna Foundation, Tofo Beach, Mozambique.
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Five species of sea turtle are found in Mozambican waters. All have been protected by national laws since 1965. Despite national protection, the illegal take of sea turtles is widespread and usually goes unpunished (Louro *et al.* 2006). Information on quantities and motives for take, cultural significance, and geographic hotspots are urgently needed to inform conservation and management actions.

Here we present information on the traditional take and use of sea turtles as revealed by semi-structured interviews with artisanal fishers from Dovela village, Inharrime, in southern Mozambique (Fig. 1).

The turtles of Dovela: Nesting along this coast occurs from November to February each year and is dominated by loggerhead turtles *(Caretta caretta)*, although some leatherback *(Dermochelys coriacea)* nesting does occur. In this region and on the rest of the turtle nesting beaches of the Inhambane Province, nests are scarce. In the 2014/2015 nesting season, four nests were recorded (Fernandes *et al.* 2015). However, anecdotal reports from both fishers and expatriate residents in the area indicate that nesting effort was greater one to two decades ago. In addition to low nesting rates, most nests do not complete a full incubation period as they are frequently raided for their eggs.

Evidence (carapaces and bones) of illegal take can be detected along the provincial coast all year round, suggesting that illegal take is not restricted to emerging females or their eggs. In light of a possible decrease in nesting turtle populations and a lack of quantitative historical data on nesting activity, we sought to document (a) traditional beliefs and values relating to sea turtles, (b) whether these cultural values are still held, and (c) whether they are a driver of illegal take. Information was gathered through interviews with 10 key people, all local fishers and residents of Dovela. The interviewees were

Figure 1: Study site, Dovela village located in southern Mozambique.

identified using the snowball sampling technique (Goodman 1961).

Photo: Sharron Basson

A typical coastal village, Dovela: Dovela is a small coastal village, located approximately 400 km north of the nation's capital, Maputo. From the main highway (EN1) it is a further 10 km along dirt tracks towards the ocean before the village is reached. The village is situated around an inland closed coastal lagoon system that runs parallel to the coast. Within the village there is a primary school and one small ecotourism lodge. The nearest town, Inharrime, is 20 km to the south, once back on the EN1. Throughout the Province, 50-70% of the population lives below the poverty line (Republic of Mozambique Ministry of Planning and Development 2010). Literacy levels reflect these statistics. In rural areas and amongst females, the rates are even higher. Although the national language is Portuguese, a local dialect M'Chope is more commonly spoken in the village.

The prevalence of take: All interviewed fishers were aware of or had partaken in the consumption of sea turtle meat or eggs. However, most (n= 7) also indicated that turtle take and consumption was never a regular activity (in past or present times). Interviewed fishers referred to take as a traditional activity, which involved a ceremony before the meat could be cut up, divided between people, and then cooked and eaten. Some of the older interviewees had not consumed turtle meat since they were children, or since Portuguese colonial times (Mozambique declared independence in 1975). They also promptly declared that their children had never eaten turtle meat.

Photo: Jess Williams

Preferences for meat: A common theme was the fact that not everyone likes turtle meat. "*Traditionally, people here eat turtles and I don't know why that is because fish is much better and it does not smell like the turtle's meat does. I have no clue why it is a tradition to eat turtle!*" "*Our families eat rice and cassava leaves like everyone else. If we catch crayfish we sell it, as it has the best value. If we eat meat, we eat fish or mussels. Sometimes if I do not manage to catch a fish from the ocean, I will buy a fish caught from the lake.*"

Decreasing trends: The interviewees noted decreasing trends regarding both the consumption of turtles and the decline in numbers of nesting females. "*Years ago people used to eat turtles, but at the same time, back then there were more turtles coming to nest, at least 20 per year and I would also say more species than we see today.*"

For sale or consumption?: Several references were made to suggest that there is some cultural taboo against the sale of turtle meat. "*The turtle is a gift from God, we cannot sell it*". "*Here, nobody sells the turtles, their meat has to be eaten, we can't sell it. It's like the mussels, you eat them, you don't sell them*."

The traditional ceremony: The interviewed fishers revealed several versions of a traditional ceremony relating to sea turtles and their harvest. One fisher recounted, "*My grandfather was the chief of the village so when someone caught a turtle, he had half of the animal*." He explained that the head of the turtle had to go to the "regulo" (chief of the greater area) but half of the turtle was for the chief. A front flipper was allocated to the fisher who caught it, the other front flipper and a hind flipper were for the leader, and the rest was divided by the chief among those who had helped the catch. The leader had to walk to the beach each time a turtle was caught and before dividing the pieces of the turtle he conducted a small ceremony with a machete "patting" on the shell of the dead turtle and saying something like "*Welcome, our ancestors gave this to us. Others have given this to us to sustain us.*" He recalled that the "regulo" at that time did not eat the turtle because he did not like it, but he used to give it to the wise men, the senior members around him.

Thanking our ancestors and offering to the ocean: Another of the interviewed fishers told the story of how he knew of traditions regarding turtles because when he was growing up his father was the village chief. He described two parts to the traditional ceremony related to the hunting of turtles. When someone caught a turtle, this information had to be disclosed to the chief. The chief then conducted the first part of the ceremony before going to the beach to see the captured animal. The chief performed a small ceremony at home where he asked the ancestors to go with him to the beach to help guide him when he cut the turtle. With this calling to the ancestors he performed a small prayer. Once at the beach, a small piece of the turtle meat, half the size of a hand, needed to be cut and grilled, and then a prayer was done. The prayer was to thank the ancestors for the gift of the turtle and to ask them to send more turtles. After this was completed, the piece of grilled meat was put at the tide line and left until the ocean took it away.

Photo: Sharon Basson.

Cutting up the catch: The turtle was cut with a special blade, similar to a machete. The plastron was cut open laterally into halves. Then the front and back flippers were cut off. The head, the heart and one of the rear flippers along with the meat around the rear flipper joint were transported to the "regulo." The transporters were given 'tontonte' (local alcohol) or 50 MZN (US$1) to deliver this to the "regulo." A front flipper was given to the village chief and the other to the fisher who killed the turtle. The final hind flipper was shared with all the others who helped to cut up the turtle. The rest of the turtle, including anything that was left from its interior, was for the village. The meat was cooked up at the chief's house and eaten with the people. In addition to the offering to the ocean, another piece of the meat was grilled and given to the grandchildren of the chief, (even if his children were adults at the time). It was important that the chief's grandchildren ate the meat. "*For each and every turtle, the tradition was the same. My father, the chief,*

had to go to the beach each time a turtle was caught."

A garden offering: An alternative version of the ceremony was described again in two parts. First, the chief would send someone to the beach when the news had been received of a turtle being caught. The chief's assistant would open and '*peel*' the turtle carcass. A wooden stick was specially cut and used to mount the turtle pieces and then it was carried back to the chief's house. The first piece of meat was grilled at the beach and given back to the sea in conjunction with some prayers to the members of their families who had died a long time ago. Once back at the chief's house, another piece of the meat was cut, grilled, and then mounted on the stick that was used to transport the turtle from the beach. This stick with the grilled meat was placed in a special area of the chief's garden, allocated as a prayer area. The offering was not allowed to be touched by anyone and it remained in the garden until it had rotted away.

A loss of tradition, a loss of turtles: Interviewed fishers remarked that the traditional ceremonies surrounding the hunting and consumption of turtles were no longer occurring. "*Catching a turtle was not so often, it was more than today but not so often. Today, there is no more tradition so there are less turtles coming to nest. Today, no one knows how to pray properly, the content has been forgotten*." Some of the interviewed fishers attributed the decline in numbers of nesting turtles to the lack of traditional values and ceremonies occurring. "*Today, there are still many turtles in the water but they don't get out of the sea because they are not called anymore. There is no more tradition to ask them to get out of the water. They are not called, so they don't get out, that's all!*"

While physical evidence of illegal take is widespread and can be found year-round, the interviewees indicated that the traditional take of turtles and ceremonies to accompany such activities are occurring less frequently.

Similarly, a loss of tradition surrounding turtle take has also been described in other parts of the Western Indian Ocean region (Frontier Madagascar 2003). Our interview responses show that while traditional values may have once been a driver for take, it is not likely to be the main motive for take in the present day in Dovela village. However, Mozambique's coastline extends almost 2,700 km and has a rich cultural diversity. The prominence and specifics of traditions regarding turtles are likely to vary amongst the cultures of local people. Although our interviews indicated that the frequency of capture and consumption is low in Dovela, these practices still occur in other places.

Traditional take and cultural significance are not commonly viewed as compatible values for achieving effective species conservation. More consideration of the cultural significance of turtle take is needed with regards to how to account for such traditional behaviours within western-value based species management frameworks. Reflecting on the limited conservation success (where effective protection has been restricted to the southern nesting beaches and near-shore waters of the Ponta Do Ouro Marine Partial Reserve) that has been accomplished in Mozambique, despite more than fifty years of marine turtle specific legislation, suggests that a new approach to marine turtle conservation and management in Mozambique may be required (Fernandes *et al.* 2015).

Given the clandestine and sensitive nature of discussing the hunting of sea turtles, we must acknowledge that these responses present part of the narrative of traditional turtle take, but perhaps not the whole story. Our results are likely to be limited by methodological constraints such as language barriers and interviewer effects, and the concern for the fishers' responses implicating them in a way that might force them into livelihood changes. However, this is the first time that traditional anecdotes regarding sea turtle take and use have been documented in Mozambique and we believe that this work will

help convey the significance of understanding and documenting the ethnography of an area before implementing conservation actions, given its likely influence in the success or failure of such efforts.

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3.3 Example of community outreach activity in Dovela (blog post).

Hope for turtles: A little village called Dovela

JL Williams.

Originally published online (07.12.2015):

https://mozturtles.com/2015/12/07/hope-for-turtles-a-little-village-called-dovela/

Leatherback and Loggerhead sea turtles nest primarily in the south of Mozambique. The majority of this nesting action occurs within the Ponta Do Ouro Marine partial reserve (PPMR), which is lucky because they have managed to curb the poaching of nesting turtles and raiding of eggs. However outside of the PPMR nesting effort is scattered along the coast and the turtles are at high risk of illegal harvest or becoming by-catch in coastal artisanal fisheries on the way to returning to their mating and nesting areas.

A few years ago, we discovered that there seemed to be a relatively stable consistent number of leatherback and loggerhead turtles nesting along Manhame Beach, 10km north of Zavora nearby to Dunes de Dovela Eco Lodge. These turtles, unlike the rest of their nesting cohort in the PPMR face significantly more risks during the process to come ashore and nest on this remote beach. Since then, with this discovery, we have begun to focus our efforts here at this location with the support of Alex, Thomas and the rest of the team at Dunes de Dovela Eco Lodge.

Dovela village, is remote and there are not many opportunities for employment. Many people rely on fishing for subsistence. Here in Dovela, the majority of the fishing is done from the beach, with hand lines or reels, unlike other parts of the surrounding coast a number of fishing practices such do not occur, from a combination of either logistical, environmental or financial reasons. Either way, the fishing community of Dovela have a much lesser impact on nesting and foraging turtles than other nearby communities.

Message written in sand by local fisher announcing he found and reported the nest.

In the past few seasons, we have been collaborating with fishers so that when they encounter a nesting turtle or track this information is reported back to the lodge and then appropriate plans are made to ensure the safe incubation of the eggs in-situ. This concept is working well and fishers are enthusiastic to listen and learn about the turtles and they often accompany us when we make an expedition to survey a nest site or excavate a nest to determine hatch success.

Two fishers observe a leatherback nest excavation.

We also wanted to know more about the type of fishing in the area and understand the attitudes towards fishing for turtles and how frequently they might encounter turtles and their general ideas about changes in marine resources in their area and perceptions about the future, so Alex (Dunes de Dovela) has been helping to collect interviews with fishers to document this. The interviews have helped us to understand the local context much better and for the first time to document some of the traditional values sea turtles have within the fishers' culture. The interviews have also highlighted to us, just how little many people in the area know about the life cycle of a turtle and whilst they knew there were laws created to protect turtles, did not understand why these laws were needed.

Seizing this opportunity and the fact that it is the beginning of the nesting season, we decided now more than ever, was the appropriate time to host an informative outreach session about sea turtles, their biology, threats and steps necessary for protection. After consulting the village chief, a time and place was agreed upon and the local school, Dovela EPC was selected for our presentation.

Dovela EPC, the local primary school.

Notices were pinned to trees throughout the village inviting all to attend.

We were lucky enough to get a full house for our presentation. Over 45 adults attended, including village chiefs and the traditional chief, the staff from Dunes de Dovela, many of the fishermen and more than 100 children from the school.

We spoke about how turtles are long lived, just like us and that they reach sexual maturity at a very late age (mean age to reach sexual maturity in Western Indian ocean loggerhead turtles is 36 years). Most of the audience did not know either of these facts.

Full house in the largest classroom of Dovela EPC for a lecture about sea turtle biology and conservation.

We also, discussed the lifecycle of the turtle and the different habitats and threats a turtle faces in each stage. Where possible we gave local examples, of human created threats that resulted in turtle mortality in surrounding areas, like how fishers using gill nets were responsible for the capture and resultant drowning of a mature loggerhead turtle in Praia de Rocha the week before. Or how we had found evidence of plastic pollution inside juvenile green turtles' resident on our inshore reefs.

Open forum session. Community Q and A.

At the end of the presentation, we had time to discuss ideas, answer questions and were humbled to receive some positive feedback and gratitude from the older fishermen. One in particular, addressed the room to tell us how he did not know about the old age or late reproductive age for turtles. He went on to say that as a boy before the civil war, he and his brothers and sisters were raised eating turtles in the season, they did not know any reason not to. After the war, the Portuguese tried to disseminate ideas of protecting turtles throughout the villages, however they did not explain why? He agreed that in recent years, there were all seeing fewer turtles returning to their beaches. Now that he knew about the hard life of the turtle and the hassles it must overcome to return to their beaches, he understood why they must work together to protect their turtles. He and several other elders made statements to the room agreeing that it was necessary as a community to act as a united force to protect their turtles and allow their future generations the chance to see and celebrate such magnificent creatures.

Celebrating newfound knowledge, Dovela- a proud and united force for their tartarugas.

Appendix 4

(Chapter 6- Perception of threats)

4.1 Expert Opinion Questionnaire

Part 1- Consumptive use of sea turtles in Western Indian Ocean

Direct harvest of turtles at sea or on the beach (through spearfishing or hunting nesting females) has been documented within the WIO region. However, the extent of these (illegal) activities are unknown. Spear fishers have also indicated that turtles are hunted opportunistically when larger game fish are not available and gill-netting/drift netting for turtles is also known to occur (both opportunistically and targeted). In addition, nest raiding (i.e. egg collection) is prevalent in some parts of the WIO region.

1. Are you aware of these activities occurring in Mozambique?

   ☐ Yes –all

   ☐ Yes some (which):

   ☐ No

2. Do you know the extent of the activities, and the species they impact? (*please specify which countries and geographic area/s*)

   Comments:

3. How concerned are you with illegal harvesting in Mozambique compared with the rest of the regional WIO marine turtle populations? *Please explain the reason behind your level of concern*.

4. In you view, how much does egg consumption impact regional (WIO) turtle populations?

5. Can you rank which species are most affected by turtle meat consumption? If yes, assign how affected consumptive uses are to each species

1- Very affected by, 2- affected, 3- slightly affected, 4- Not affected.

Green Turtles:	1	2	3	4	Don't know
Loggerhead turtles:	1	2	3	4	Don't know
Leatherback Turtles:	1	2	3	4	Don't know
Hawksbill Turtles:	1	2	3	4	Don't know
Olive Ridley Turtles:	1	2	3	4	Don't know

Comparative species ranking (affected by egg consumption;1 is very affected - 5 is least affected):

1:

2:

3:

4:

5:

Comparative species ranking (affected by turtle meat consumption; 1 is very affected - 5 is least affected):

1:

2:

3:

4:

5:

Part 2- Conservation and Management Stakeholders

6. What management and conservation initiatives related to marine turtles in Mozambique are you aware of (past or present)?

   Past:

   Present:

7. Are any of these (from above) still running? – which?

8. Have any (past or present) been effective in improving the conservation of marine turtles? (*please detail*):

9. In your view, are any likely to be successful if they are continued? Why? (*please detail*)

10. To what extent do you agree that sea turtle conservation initiatives within Mozambique are necessary for regional marine turtle populations? (*Please select a score from below*)

1	2	3	4	5	6
Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Don’t know

Response: ____________________________________

Part 3-Effectiveness of Existing Legislation, Policy, Enforcement and Management Activities

11. Are marine turtles protected by law in Mozambique?

    ☐ Yes

    ☐ No

    ☐ Unsure

12. What factors influence the success of marine turtle legislation and policy ? *(Please detail if your answer is specific to Mozambique or the wider WIO region).*

    My response is specifically referring to:

    ☐ Mozambique

    ☐ WIO region

    ☐ Other:

    Negative Factors:

    Positive Factors:

13. Is it necessary to strengthen legal initiatives within Mozambique for the management of marine turtles?

    ☐ Yes

    ☐ No

    ☐ Unsure

    Comments:

14. In your view, what is needed to improve enforcement efforts? *Please list and rank your ideas where in terms of priority levels (1 most- xx least).*

15. What do you think are the most important tools to improve current conservation and management in Mozambique? *Please list and rank your ideas where in terms of priority levels (1 most- xx least).*

16. How important is the role of the Mozambique Government in sea turtle conservation and management? *Please circle your response*

1	2	3	4	5
Not at all important	Low importance	Neutral	Moderately important	Extremely important

17. How important is the role of non-governmental organizations (non-profits, or universities) in Mozambique? *Please circle your response*

1	2	3	4	5
Not at all important	Low importance	Neutral	Moderately important	Extremely important

18. What organisations (or types of organisations) to you feel have a role in the future conservation/management efforts for marine turtles in Mozambique?

Please consider government, universities, non-profit organisations, external aid and charities, large international non-governmental organisations (e.g. WWF, FFI, WCS), *local community and any others. Please list and rank your ideas where 1 most important organisation/greatest contributor for the future of conservation and management efforts and XX is the least.*

19. Are you familiar or are you a member of the GTT (Groupo de trabalhar de Tartarugas marinhas em Moçambique) the Mozambican marine turtle working group?

☐Yes

☐ No

20. How valuable do you think having an active GTT is? *Please circle your response.*

1	2	3	4	5
Not valuable	Slightly valuable	Somewhat valuable	Moderately valuable	Extremely valuable

21. If an active GTT existed in Mozambique, what are the most beneficial features you would like it to provide to you as a stakeholder in sea turtle conservation, management or enforcement? *Please list them and indicate their priority.*

Part 4: quantify the relative impact of threats- pairwise comparison ranking.

22. Please rank the following factors against each other in the table below- according to the following scale:

Please keep in mind when answering this question, that we want your opinion of the threat level of each of these factors to sea turtle populations that utilize the Mozambican coast, or Western Indian Ocean region.

a) Which geographic are and/or species do you have in mind when you answer this?______________________

- *Hunting of nesting turtles- This refers to targeted hunting of nesting females whilst on the nesting beach or emerging from the shallows to nest.*
- *Egg harvesting- the collection of eggs from nests.*
- *Direct hunting of foraging turtles- Via intentional fishing activities aimed at capturing turtles e.g. spearfishing.*
- *By-catch Commercial fisheries – trawlers*
- *By-catch commercial fisheries- long-lining*
- *Coastal habitat modification (inc. artificial lighting)*
- *Vessel strike*
- *In-direct hunting of foraging turtles- non-target fishing of foraging turtles e.g. opportunistic spearfishing or gillnetting when target fishes are in low abundance.*
- *By-catch from artisanal fisheries (Gill nets, purse seining, long-lines, beach seining)*
- *Plastic debris- including the effects of ingestion and or debris.*
- *Climate change- Temperature*
- *Climate change- Sea level rise*
- *Climate change- Cyclone*

Example response:

	Vessel strike	By-catch commercial fisheries- long lining
Hunting of nesting turtles	7	5
Egg harvest	7	7

- Please write your scores in the relevant cell in the following table.

X **Extremely** more important Y	X **Moderately** more important Y	X **Slightly** more important Y	**Equal** importance	Y **Slightly** more important X	Y **Moderately** more important X	Y **Extremely** more important X
1	2	3	4	5	6	7

Comparative threat matrix: see next page.

		X threat factors								
Y threat factors		Hunting of nesting turtles	Egg harvest	Direct hunting of foraging turtles	By-catch Commercial fisheries - trawlers	By-catch commercial fisheries- long-lining	Coastal habitat modification (inc artificial lighting)	Vessel strike	In-direct hunting of foraging turtles	By-catch from artisanal fisheries
	Hunting of nesting turtles									
	Egg harvesting									
	Direct hunting of foraging turtles									
	By-catch Commercial fisheries - trawlers									
	By-catch commercial fisheries- long-lining									
	Coastal habitat modification (inc. artificial lighting)									
	Vessel strike									
	In-direct hunting of foraging turtles									
	By-catch from artisanal fisheries									
	Plastic debris									
	Climate change- Temperature									
	Climate change- Sea level rise									
	Climate change- Cyclones									

X **Extremely** more important Y	X **Moderately** more important Y	X **Slightly** more important Y	**Equal** importance	Y **Slightly** more important X	Y **Moderately** more important X	Y **Extremely** more important X
1	2	3	4	5	6	7

23. Are there other threats not listed in the table above that impact turtles in Mozambique?

Please list them and indicate their priority.

4.2. Scientific poster based on chapter 6.

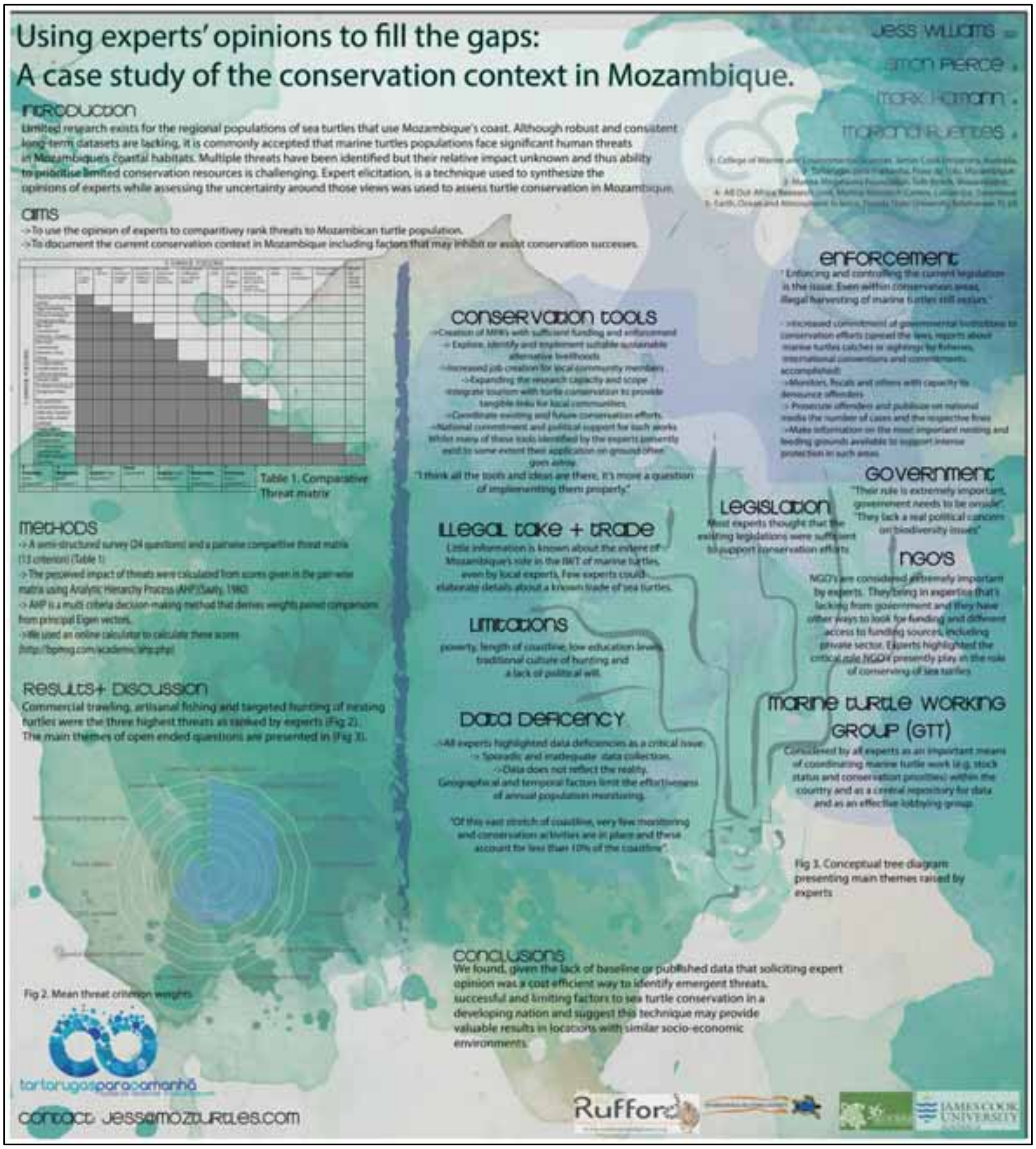

Fig S4.1. Scientific poster based on Chapter 6 presented at the 36th Annual International Sea Turtle Symposium, Peru 29th Feb- 4th Mar.