Exploitation of marine turtles and elasmobranchs in Madagascar

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature:

Abstract

Small-scale fisheries (SSF) are poorly documented, yet 90% of the 120 million employed in capture fisheries work in the SSF sector and >1 billion people globally rely on fish as an important source of protein. There is a lack of data on the status of the majority of fisheries in Madagascar owing to the difficulty in surveying the vast coastline and large number of small-scale fishers. In Madagascar, marine turtles and elasmobranchs are important culturally and as sources of income and food for many small-scale fishers. However, very little data exist on the status of these two animal groups. The five chapters of this thesis intend to increase our understanding of the status of marine turtles and elasmobranchs in Madagascar. This is achieved through the assessment of the fisheries, legislation and in the case of turtles, the nesting population. I also document community-based methods for monitoring fisheries and marine turtle nesting, that are easily replicable for gathering data across remote regions. Results show that the turtle fishery in Madagascar appears to have remained at the same level since the 1970s, despite being illegal since the 1990s, with landings estimated to be approximately 10,000 to 16,000 turtles.year^{-1}. To further contextualise the take of turtles in Madagascar, by carrying out a global review, I estimate that the worldwide legal take in turtle fisheries to be over 42,000 turtles.year^{-1}. Contrary to reports from fishers, actual numbers of elasmobranchs (the majority of which are sharks) taken by the traditional (non-motorised) fishery has not declined. Results support previous reports that fishing effort has increased, as well changes in fishing gears, to account for declining catch per unit effort (CPUE) to maintain shark landing numbers. Furthermore, the size of some shark species has significantly declined, even across this study. Community-based turtle nesting monitoring and protection in western Madagascar revealed a small, yet potentially significant, nesting population. Across the 17 current nesting sites recorded, the majority of nesting populations in Madagascar have <50 nests.year^{-1}. A further >40 historic nesting sites were recorded. Community-led monitoring methods not only helped to fill a data gap, but were also found to reduce loss of nests through human disturbance. Misinterpretations, poor enforcement and gaps in current legislation mean that both marine turtles and elasmobranchs are effectively unprotected from overexploitation. This thesis provides recommendations for improved legislation and management of both groups of species and demonstrates that participatory monitoring methods can not only reduce data deficiency, but enhance locally-led management and protection, and increase Madagascar's capacity for improved management and conservation.

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Acknowledgements

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Special thanks go to my two supervisors, Annette Broderick and Brendan Godley, for providing guidance, advice and support since 2007. Special thanks also to my particular colleagues at Blue Ventures Conservation, Alasdair Harris, Charlie Gough and Garth Cripps for their support, advice and knowledge. In particular I must thank Thomas Beriziny, a friend and colleague who is no longer with us, but without which much of this work have been impossible due to his relationship with the community in Madagascar, and knowledge of the traditional fisheries.

I would like to thank the many fishermen and community data collectors that made this study possible and contributed their time and energy to helping me understand the traditional shark and marine turtle fisheries.

Finally I would like to thank those that funded much of this work: The Rufford Foundation, National Geographic Conservation Trust, SeaWorld and Busch Gardens Conservation Fund, British High Commission of Mauritius and The State of the World's Sea Turtles (SWOT).

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Country abbreviations (countries in brackets indicate dependency): ALB = Albania; AND = Andaman and Nicobar Islands (India); AUS = Australia; BOS = Bosnia and Herzegovina; CHI = Chile; COP = Colombia (Pacific coast); GUY = Guyana; IND = Indonesia; JAP = Japan; KIR = Kiribati; MAL = Maldives; MAR =

Marshall Islands: MIC = Federated States of Micronesia; MXA = Mexico (Atlantic coast); MXP = Mexico (Pacific coast); PAL = Palau; PAP = Papua New Guinea; PIT = Pitcairn Islands (UK); SAO = Sao Tome and Principe; SYR = Syria.

Species breakdown is also shown for countries with unverified legislation (ALG = Algeria; NKO = North Korea; SOM = Somalia).

Note: Position of symbols is not representative of locations of take data.

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Country abbreviations (countries in brackets indicate dependency): Figure S3a: ANG = Anguilla (UK); ANT = Antigua and Barbuda; BEL = Belize; BRI = British Virgin Islands (UK); CAY = Cayman Islands (UK); COA = Colombia (Atlantic coast); DOM = Dominica; GRE = Grenada; HAI = Haiti; HON = Honduras; MON = Montserrat (UK); NIA = Nicaragua (Atlantic coast); STK = St. Kitts and Nevis; STL = St. Lucia; STV = St. Vincent and the Grenadines; TUR = Turks and Caicos (UK).

Species breakdown is also shown for countries with unverified legislation: PAA = Panama (Atlantic coast). These data were not included in grouped data for CAR in Figure S2.

Country abbreviations (countries in brackets indicate dependency): Figure S3b: COO = Cook Islands (New Zealand); FIJ = Fiji; NAU = Nauru; NEW = New Caledonia (France); NIU = Niue; SAM = Samoa; SOL = Solomon Islands; TOK = Tokelau (New Zealand); TON = Tonga; TUV = Tuvalu; VAN = Vanuatu; WAL = Wallis and Futuna (France).

Note: Position of symbols is not representative of locations of take data.

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Country abbreviations are (countries in brackets indicate dependency): ALB = Albania; AND = Andaman and Nicobar Islands (India); ANT = Antigua and Barbuda; AUS = Australia; COA = Colombia (Atlantic coast); COP = Colombia (Pacific coast); GRE = Grenada; GUY = Guyana; HAI = Haiti; HON = Honduras; MAR = Marshall Islands; NIA = Nicaragua (Atlantic coast); PAL = Palau; PAP = Papua New Guinea; SOL = Solomon Islands; SAO = Sao Tome and Principe; TON = Tonga; STL = St. Lucia; STV = St. Vincent and the Grenadines; TON = Tonga; TUR = Turks and Caicos (UK); VAN = Vanuatu. Numbers above bars on graphs (a) (c) and (d) indicate actual data value. *Legislation prohibits take in Principe only since 2009.

Table S1. Estimated current annual legal take by species for countries with legal marine turtle fisheries as of 1st January 2013.

ND = No data found. A = Species absent. R = Species rare. P = Species fully protected. NA = Not applicable. 0 = No legal take known.

Country abbreviations (countries in brackets indicate dependency): ALB = Albania; ALG = Algeria; AND = Andaman and Nicobar Islands (India); ANG = Anguilla (UK); ANT = Antigua and Barbuda; AUS = Australia; BEL = Belize; BOS = Bosnia and Herzegovina; BRI = British Virgin Islands (UK); CAY = Cayman Islands (UK); CHI = Chile; COA = Colombia (Atlantic coast); COO = Cook Islands (New Zealand); COP = Colombia (Pacific coast); DOM = Dominica; FIJ = Fiji; GRE = Grenada; GUY = Guyana; HAI = Haiti; HON = Honduras; IND = Indonesia; JAP = Japan; KIR = Kiribati; MAL = Maldives; MAR = Marshall Islands: MIC = Federated States of Micronesia; MON = Montserrat (UK); MXA = Mexico (Atlantic coast); MXP = Mexico (Pacific coast); NAU = Nauru; NEW = New Caledonia (France); NKO = North Korea; NIA = Nicaragua (Atlantic coast); NIU = Niue; PAA = Panama (Atlantic coast); PAL = Palau; PAP = Papua New Guinea; PIT = Pitcairn Islands (UK); SAM = Samoa; SAO = Sao Tome and Principe; SOL = Solomon Islands; SOM = Somalia; STK = St. Kitts and Nevis; STL = St. Lucia; STV = St. Vincent and the Grenadines; SYR = Syria; TOK = Tokelau (New Zealand); TON = Tonga; TUR = Turks and Caicos (UK); TUV = Tuvalu; VAN = Vanuatu; WAL = Wallis and Futuna (France).

[1] Andaman and Nicobar Islands are a Union Territory of India.

[2] Anguilla, British Virgin Islands, Cayman Islands, Montserrat, Turks and Caicos and Pitcairn Islands are all overseas territories of the UK.

[3] The Cook Islands are self-governing in free association with New Zealand.

[4] New Caledonia is a territorial collectivity (or a *sui generis* collectivity) of France since 1998.

[5] Tokelau is a self-administering territory of New Zealand.

[6] Wallis and Futuna is an overseas territory of France.

[+] No national estimate available, local estimate only.

Numbers in parentheses indicate that some was data originally unidentified by species.

[a] Best guess, not an official estimate.

[b] Includes current or historical direct take estimates (not presented here) calculated using volumes of bekko or meat.

[c] Includes unidentified data broken down into species before calculations (either current and/or historical data).

[d] Only data on poached nesting females.

[e] To be noted: Department has limited information and all Nevis fishers were not willing to cooperate in providing information.

Leg. Cat. = Legislation category (see Figure 1). Legislation categories:

N = Protection absent [some islands or communities have their own regulations]*protection administered at some level through other regulations

L = Legislation allows for a level of harvest of one or more species of turtles [permit/licence required] [[subsistence only]]{ad hoc agreement in Bali for approximately 300-400 turtles/year from hatcheries to be used in religious rituals despite all species being protected}*banned in Principe ^written cabinet approval.

T = Full protection but traditional hunting exemptions exist [permit/licence required] [[personal/domestic use only]] **licence granted for those who traditionally hunted turtles.

M = Moratorium in place only at present [permit/licence required]

U = Unable to verify legislation. *In Panama the legal situation is considered confused as although all turtles species were protected in 1980 other laws allow subsistence fishing and recognise traditional user rights. **Due to the fact that several autonomous regions now exist in Somalia, there is no national legislation to protect marine turtles. However, in Puntland State turtles are protected by a local decree and are fully protected by law in Somaliland.

Appendix S1. Supporting references.

Chapter 3

Assessing the small-scale shark fishery of Madagascar through community-based monitoring and knowledge

Table 1. Recorded shark landings for each village in the study. The number of months of monitoring per year is included in brackets. Region 1 = Andavadoaka (Figure 1) and Region 2 = Belo-sur-Mer (Figure 1). DR = Data collection occurred but data removed during verification process. Dashes indicate no data collection occurred. Human population data from Oleson *et al.* unpublished data; Jones 2012; ACDEM census; Fokontany 2013; [a]No official survey done, estimation by Blue Ventures; *Monthly census data collected between October 2009 and March 2011 by Blue Ventures.

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was converted to estimated Total length (TL) for scalloped hammerheads and sliteye sharks using equations in Table S1. Size class is pre-caudal length for graphs e-f. Graphs a to d: Dotted lines on graphs a to d represent minimum TL at maturity: scalloped hammerheads 212 cm (female) and 140 cm (male); sliteye 79 cm (female) and 62 cm (male) (Compagno 1984).Graphs e to f: Dotted lines indicate minimum PCL (~158 cm) at maturity for *R. djiddensis*. Dashed lines indicate maximum PCL (~125 cm) for *R. annulatus.* Minimum PCL at maturity and maximum PCL were calculated from known length-length equations for *R. djiddensis* (Table S1) (Fishbase.org).

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Reference abbreviations: 1 Robinson & Sauer 2013; 2 McVean *et al.* 2006; 3 Cooke 1997; 4 Doukakis *et al.* 2011.

NW, SW, SE, W, N, NE, E represent geographical regions. Specific location abbreviations: TOL = Toliara; TOG = Tolagnaro; MOR = Morombe; MOD = Morondava; MAH = Mahajanga; ANT = Antseranana; SAM = Sambava; STM = St. Marie; TOA = Toamasina; MAN = Mankara; NBE = Nosy Be.

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References for each site number are: 1 & 14: Metcalf et al., 2007; 2 & 17: Mealla, 2011; 3: Rasolofo, 2012, Elst et al., 2012 ; 4: CEDTM, 2001, Rasolofo, 2012; 5: Gladstone et al., 2003; 6: IOSEA, 2011, Elst et al., 2012; 7: G. Tovondrainy pers. comm.; 8 & 9: Walker & Roberts, 2005; 10: IOSEA, 2011; 11-13: Blue Ventures (this study); 15: Bourjea et al., 2006, Allison, 2008; 16: Sagar, 2011. Further information is available in Table S1 and S3.

Figure 3. Map of current known nesting sites surrounding Madagascar. Current known nesting sites and sizes are shown as circles and represent annual number of nests. Asterisks highlight data based on (**) nesting turtles year^{-1} and (***) track counts. No attempt was made to extrapolate nesting given for a period less than a year. The origins of tags retrieved by Blue Ventures in Madagascar are highlighted.

References for each site number are: 18 & 30: Elst et al., 2012, Lauret-Stepler et al., 2007; 19: Bourjea, 2012 in Elst et al., 2012; 20: Bourjea et al., 2007; 21: Lauret-Stepler et al., 2010; 22: Elst et al., 2012, Lauret-Stepler et al., 2007; 23: Garnier et al., 2012; 24-28: Videira et al., 2011; 29: Nel, 2010; 31: Ciccione & Bourjea, 2006.

More information is available in Table S2.

Figure 4. Green (a) and hawksbill (b) turtle nesting counts by half month over the 3 year survey period for the three islands monitored each season (Nosy

Abohazo, Nosy Andrano, Nosy Dondosy). Data have been interpolated for the gaps in monitoring during the survey period. Dots indicate periods where there were no surveys between 26th May 2012 and 14th December 2012, and 19th May 2013 and 13th December 2013. Asterisks indicate incomplete 14 days of monitoring where data included have been interpolated.

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Table S1: Current nesting in Madagascar, its size, location and species. Species codes are Cm = green, Ei = hawksbill, Cc = loggerhead, Lo = olive ridley, Dc = leatherback, Un = Unknown. Site numbers refer to labels on Figure 2.

References for each site number are: 1 & 14: Metcalf et al., 2007; 2 & 17: Mealla, 2011; 3: Rasolofo, 2012, Elst et al., 2012 ; 4: CEDTM, 2001, Rasolofo, 2012; 5: Gladstone et al., 2003; 6: IOSEA, 2011, Elst et al., 2012; 7: G. Tovondrainy pers. comm.; 8 & 9: Walker & Roberts, 2005; 10: IOSEA, 2011; 11-13: Blue Ventures (this study); 15: Bourjea et al., 2006, Allison, 2008; 16: Sagar, 2011.

Table S2. Records of regional known nesting sites in the islands surrounding Madagascar, Mozambique and northern South Africa. Species codes are Cm=

green, Ei = hawksbill, Cc = loggerhead, Lo = olive ridley, Dc = leatherback, Un = Unknown.

References for each site number are: 18 & 30: Elst et al., 2012, Lauret-Stepler et al., 2007; 19: Bourjea pers. comm. in Elst et al., 2012; 20: Bourjea et al., 2007; 21: Lauret-Stepler et al., 2010; 22: Elst et al., 2012, Lauret-Stepler et al., 2007; 23 Garnier et al., 2012; 24-28: Videira et al., 2011; 29: Nel, 2010; 31: Ciccione & Bourjea, 2006.

*Data used for analyses started in 1992 due to gaps in full years of data collection.

Table S3. Records of historical (defined as pre 2000) known nesting sites in Madagascar and possible species. Species codes are Cm = green, Ei = hawksbill, Cc = loggerhead, Lo = olive ridley, Dc = leatherback, Un = Unknown. No size of annual nesting was given for any of these nesting sites.

References for each site number are: 4: CEDTM, 2001; 9: Walker & Roberts, 2005; 11-13: Blue Ventures (this study); 16: Sagar, 2011.

Chapter 5

Endangered, essential and exploited: how extant laws are not enough to protect marine megafauna in Madagascar.

Table 1 The hierarchy of legislation within Madagascar (with 1 being the highest).

Table 2 Past and current regulations that protect marine turtles in Madagascar. Relevant text from each piece of legislation is provided in Supplementary material Appendix S1.

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Table 4 Shark families and species forbidden as bycatch within the EU Fisheries Partnership Agreement [53]. IUCN Red List category: NT=Near Threatened, VU=Vulnerable, EN=Endangered.

Table 5 CITES and CMS restrictions and objectives by appendices; and marine turtle and elasmobranch species listings for those found in Madagascar waters [65,66]. Species are only placed in one Appendix for CITES dependent on their conservation status whilst can be placed within Appendix I and/or II for CMS.

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Table 8 Recommendations for the improvement in legislation for elasmobranchs and marine turtles in Madagascar.

Appendix S1. Original articles of relevant legislation in Madagascar

List of Abbreviations, Acronyms and Conversions

CCL	Curved carapace length
CITES	Convention on International Trade of Endangered Species
CMS	Convention of Migratory Species
EEZ	Exclusive Economic Zone
GLMs	Generalized linear models
IAC	Inter-American Convention for the Protection and Conservation Sea Turtles
IUCN	International Union for Conservation of Nature
IOSEA	Indian Ocean South East Asia Marine Turtle Memorandum of Understanding
LMMA	Locally managed marine area
MGA	Malagasy Ariary
MRHP	Ministère des Ressources Halieutiques et de la Pêche
PCL	Pre-caudal length
SSF	Small-scale fisheries
TL	Total length
US$	United States Dollar
WIO	Western Indian Ocean

Author’s declaration of contributions to co-authored chapters/research papers

All chapters presented in this thesis were written by F.K Humber under the guidance and supervision of A.C. Broderick and B.J. Godley. Specific author contributions to chapters are detailed below:

Chapter 1: Using community members to assess artisanal fisheries: the marine turtle fishery in Madagascar

Frances HUMBER, Brendan J. GODLEY, Vola RAMAHERY and Annette C. BRODERICK

In Chapter 1, an updated status of the traditional turtle fishery in Madagascar is provided, using a network of community-based data collectors. I conducted and supervised data collection, carried out all analyses and was the lead author on the manuscript. V. Ramahery assisted with project coordination in Madagascar during the period the data were collected, including training data collectors and collecting data. The chapter was written under the supervision of A. Broderick and B. Godley who provided guidance on data analysis, structure and writing. This chapter was published in Animal Conservation in 2011.

Chapter 2: So excellent a fishe: a global overview of legal marine turtle fisheries

Frances HUMBER, Brendan J. GODLEY and Annette C. BRODERICK

A global review of legal turtle fisheries is presented in this chapter. I carried out the literature review, expert consultations, data analysis and wrote the manuscript. A. Broderick and B. Godley assisted with the design of the data analysis and well as providing guidance and comments on structure and writing of the manuscript. This chapter was published in Diversity and Distributions in 2014.

Chapter 3: Assessing the small-scale shark fishery of Madagascar through community-based monitoring and knowledge

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Community-based monitoring is used to provide the first multiyear assessment of the traditional shark fishery in Madagascar. Over six years I was responsible for project coordination and data collection in Madagascar, project supervision, data analysis and wrote the manuscript. E. Andriamahaino, R. Botosoamananto, C. Gough and V. Ramahery provided with project coordination and assistance in Madagascar. S. Pedron assisted with project coordination and helped to develop the initial project, as did T. Beriziny, who also provided advice and guidance throughout the six years of the study. The chapter was written under the supervision of A. Broderick and B. Godley who provided guidance on data analysis, structure and writing.

Chapter 4: Placing Madagascar's marine turtle populations in a regional context using community based monitoring

Frances HUMBER, Brendan J. GODLEY, Tanguy NICOLAS, Olivier RAYNAUD, Florence PICHON and Annette C. BRODERICK

In this chapter the results from Madagascar's first community monitoring and protection programme for marine turtles are presented, and contextualised with data from nesting sites throughout the region. I provided guidance and coordinated the establishment of the turtle nest monitoring programme, analysed the data and wrote the manuscript. T. Nicolas, O. Raynaud and F. Pichon coordinated nest monitoring activities in Madagascar. A. Broderick and B. Godley provided guidance on data analysis, structure and writing.

Chapter 5: Endangered, essential and exploited: how extant laws are not enough to protect marine megafauna in Madagascar

Frances HUMBER, Mialy ANDRIAMAHEFAZAFY, Brendan J. GODLEY and Annette C. BRODERICK

A review of current legislation in Madagascar relating to megafauna, in particular elasmobranchs and marine turtles, is presented in this chapter. I wrote the manuscript, and with the assistance of M. Andriamahefazafy, analysed relevant legislation in Madagascar. M. Andriamahefazafy also assisted with procuring and translating legislation. The chapter was written under the supervision of A. Broderick and B. Godley. This chapter was published in Marine Policy in 2015.

Introduction

The importance of understanding the scale and significance of small scale fisheries (SSF) for food, income and livelihoods has grown over the last decade (Béné et al., 2006, 2006; Barnes-Mauthe et al., 2013). The livelihoods of 90% of 120 million employed in fisheries are in SSF, and of these, 97% are found in developing countries (World Bank/FAO/WorldFish Center, 2010). SSF play a pivotal role in food security and poverty alleviation, and their sustainable use underpins the long-term livelihoods of millions of people across coastal communities (Béné et al., 2007; World Bank/FAO/WorldFish Center, 2010). SSF are regularly underreported or absent in national fisheries data supplied to the Food and Agriculture Organization of the United Nations (FAO), compared to industrial or export-oriented fisheries (Zeller et al., 2006; Jacquet al., 2010). There is a lack of information on the status of SSF in comparison to larger-scale or industrial fisheries, due to the fact that SSF are often numerous, targeting multiple species, are remotely located and therefore poorly or weakly regulated and managed (Wielgus et al., 2010; Zeller et al., 2011; Le Manach et al., 2012).

Small-scale fisheries are not just isolated to finfish and invertebrates, but can also include megafauna such as elasmobranchs and marine turtles (Doherty et al., 2014; Lagueux et al. 2014). In Madagascar, both groups have been important sources of income and food for small-scale fishers for centuries (Fourmanoir 1961; Hughes 1974). However, in the last few decades, the exploitation of both species has increased, with a shift from subsistence to market-driven take due to increasing coastal populations, and new national and international markets for both groups of animals (Cooke, 1997; Lilette, 2006).

Marine turtles are culturally significant in Madagascar, and hunting them is an important traditional activity for the *Vezo* fishers of southwest Madagascar (Lilette, 2007), with linked ancestral rituals and restrictions observed for capture methods and the preparation of meat (Astuti, 1995). However, many cultural practices have weakened, or been less strictly observed, often in conjunction with changes to more effective capture methods (Hughes, 1970; Astuti, 1995; Pascal 2008). Hunting turtles to sell at local markets for profit, an act once considered taboo, now drives the majority of exploitation, with the appearance of middlemen that facilitate the trade of marine turtles (Pascal 2003, 2008; Lilette 2006, 2007).

Targeted shark fishing in Madagascar developed rapidly in the late-1980s as dried shark fin prices increased with demand from China (Cooke, 1997). Although reliable figures on production at the regional and national level are scarce, an initial peak in production was thought to have occurred in the early to mid-1990s at ~30 and 60 tonnes.year^{-1} (Cooke, 1997; Le Manach et al., 2012; Cripps et al.,2015), but with current exports now estimated to be between 30 and 40 tonnes.year^{-1} (Le Manach et al., 2012; Cripps et al., 2015). Furthermore comprehensive data on sharks landed and volumes of shark fin across each of the three categories of fisheries in Madagascar (traditional: non-motorised, artisanal: <50hp engine, industrial: >50hp engine) do not exist. In addition, bycatch, targeted and Illegal, Unregulated and Unreported (IUU) take from foreign fishing vessels of sharks has increased steeply since 1950 (Le Manach et al. 2011, 2012). Today, the search for productive shark fishing grounds still drives traditional *Vezo* fishing migrations and artisanal fishers, as shark fins still fetch relatively large sums of money compared to other marine resources

(Cripps, 2009; Cripps et al. 2015); as well being targeted by foreign fishing vessels (European Commission, 2013).

Reports of declines in both groups of animals have been recorded in studies and anecdotally (Rakotonirina & Cooke, 1994; McVean et al., 2006); with observations of dramatic decreases in shark populations in southwest Madagascar (Cripps pers. comm.; Cripps et al., 2015). Despite the social and economic importance of both groups of species, and the two main groups of megafauna exploited in Madagascar, limited management and regulatory frameworks have been put in place to reduce the effects of unsustainable fishing. Marine turtles are fully protected within Malagasy law, yet take continues illegally, with limited awareness and understanding of the full status of protection within Madagascar for marine turtles (Humber & Hykle, 2011). Very little legislation exists to manage shark fishing across the different fishing sectors. Improved management and conservation of both groups of species is therefore hampered by a lack of data and a clear understanding of the status and gaps in current legislation.

The **first chapter** of this thesis describes an innovative method of using a network of community-based monitors that was developed in western Madagascar to assess the status of the marine turtle fishery. Small-scale fisheries such as these in Madagascar are data deficient for a number of reasons: the high opportunity cost of setting up fisheries monitoring, the remote coastline and a lack of financial resources and capacity. By equipping village members with notebooks and cameras and training them to collect data on turtles landed within their village, the first estimate of the turtle fishery in

Madagascar was made using actual landings data. The results of this study indicated that the level of take of turtles in Madagascar has remained of a similar magnitude since the 1970s (Frazier, 1980; Hughes, 1974; Rakotonirina & Cooke, 1994).

Chapter two assesses the global legal take of turtles, and allows us to contextualise the findings of the size of the illegal turtle fishery in Madagascar. The direct take of nesting and foraging marine turtles for meat, shell and other products has taken place for millennia (Groombridge & Luxmoore, 1989), but levels of exploitation increased radically upon western colonization of the New World (Babcock, 1938; Wayne King, 1995). Large-scale commercial exploitation peaked in the late 1960s (FAO, 2011), although international trade fuelled commercial level exploitation until the mid-1980s (Milliken & Tokunaga, 1987). Data from an extensive literature review were compiled for each country with permitted take of turtles, and cross references with experts from each country. This paper provides the first baseline for global legal turtle fisheries for future assessments, and a means with which to improve current knowledge.

The growth of the traditional and artisanal shark fishery in Madagascar was fuelled by the shark fin trade in the 1990s (Cooke, 1997). As highlighted, no legislation currently exists to manage this fishery and there have been reports of declining shark landings and the loss of sharks from nearshore lagoons in the study region, in southwest Madagascar. Although a few studies exist on the size of the traditional shark fishery, studies were often limited temporally or geographically (McVean et al., 2006; Robinson & Sauer, 2013). In **Chapter three** I describe the status of the traditional (non-motorised vessels) shark fishery in Madagascar using a six year dataset of these fisheries from Madagascar, and reveal trends in species composition and size. These data were collected via similar participatory methods as in Chapter 1, and permitted comprehensive data to be collected over a remote coastline.

Building on lessons learnt in developing community-led fisheries monitoring, and understanding the threats to marine turtle populations in Madagascar, **Chapter four** presents the results from the country’s first community-based marine turtle nest monitoring programme. The programme was set up to monitor and protect nesting populations in the remote Barren Isles, western Madagascar. The regional context within which this nesting population falls is explored, contrasting the small nesting populations found within Madagascar, the large protected nesting populations surrounding Madagascar on many uninhabited islands of the Western Indian Ocean, and the large numbers of turtles taken within Madagascar’s fisheries (Chapter 1). The methods employed in both Chapters 1, 3 and 4 also highlight the importance of participatory monitoring and the indirect benefits for increasing community capacity and buy-in for conservation and management, that can be harnessed to improve the status of protected species, as well as providing a means for cost-effective research.

A lack of understanding of current national and international legislation that Madagascar had enacted was highlighted at a national marine turtle workshop in 2010 (Humber & Hykle, 2011). As a result, in **Chapter five,** current texts in application were analysed to present the status of protection, gaps in legislation and implementation and future recommendations for both turtles and elasmobranch species. Of particular importance is that a further 21 elasmobranch species will be added to the Convention on Migratory Species (CMS) following the 2014 Conference of Parties, including two species of hammerheads regularly fished in Madagascar (CMS, 2014; McVean et al., 2006; Robinson & Sauer 2013). It is clear that both groups of species are effectively "unprotected" and that several loopholes and gaps in legislation exacerbate this.

The conservation status of many species of marine turtles and elasmobranchs is of global concern. All five species of marine turtle found in Madagascar's waters are listed on the IUCN Red List as Vulnerable, Endangered or Critically Endangered; and a recent global analysis of 1,041 shark and ray species found that a quarter are threatened, primarily as a result of overfishing, and that catches are likely to be severely underreported (Dulvy et al., 2014; IUCN Red List, 2015). In addition, almost half (46.8%) were Data Deficient and there was not enough information to assess their status (Dulvy et al., 2014). Whilst all species of marine turtle are listed on a number of multilateral agreements (eg. Convention on International Trade of Endangered Species, CITES; Convention of Migratory Species, CMS), relatively few shark species have been listed to date, although that number is now rising with increased awareness over their extinction risk (CITES, 2013; Dulvy et al., 2014; Wildlife Conservation Society, 2014). In a country such as Madagascar, the connection between these two groups of animals, as those of both high conservation concern and value, and those that play an important role in the livelihoods of thousands of small-scale fishers, highlights the need for locally-led management initiatives and national legislation that ensures that Madagascar’s marine resources are protected from overexploitation.

References

Astuti, R. (1995). People of the sea: Identity and descent among the Vezo of Madagascar. Cambridge, Cambridge University Press.

Babcock, H. L. (1938). "The sea-turtles of the Bermuda Islands, with a survey of the present state of the turtle fishing industry." Proceedings of the Zoological Society of London (A) 107: 595-601.

Barnes-Mauthe, M., K. L. L. Oleson, et al. (2013). "The total economic value of small-scale fisheries with a characterization of post-landing trends: An application in Madagascar with global relevance." Fisheries Research 147: 175-185.

Béné, C. (2006). Small-scale fisheries: assessing their contribution to rural livelihoods in developing countries. FAO Fisheries Circular. No. 1008. Rome, FAO: 46.

Béné, C., G. Macfadyen, et al. (2007). Increasing the contribution of small-scale fisheries to poverty alleviation and food security. FAO Fisheries Technical Paper. No. 481. Rome, FAO: 125.

CITES. (2013). "CITES getting ready for sharks and rays."   Retrieved August 17th, 2014, from http://www.cites.org/eng/news/pr/2013/20130914_shark_ray.php.

CMS. (2014). "Global Protection Proposed for Sharks, Rays, Sawfish, Polar Bear and Lions."   Retrieved 12th May, 2015, from http://www.cms.int/en/news/global-protection-proposed-sharks-rays-sawfish-polar-bear-and-lions.

Cooke, A. (1997). Survey of Elasmobranch fisheries and trade in Madagascar. The trade in shark and shark products in the Western Indian and Southeast Atlantic Oceans. N. T. Marshall and R. Barnett. Nairobi, Traffic East/Southern Africa: 101-130.

Cripps, G. (2009). "Understanding migration amongst small-scale fishers in Madagascar." Blue Ventures Conservation Report for ReCoMaP service contract PE2/014/2008

Cripps, G., A. Harris, et al. (2015). A Preliminary Value Chain Analysis of Shark Fisheries in Madagascar. Report SF/2015/34. Ebene, Mauritius, Indian Ocean Commission.

Doherty, P. D., J. Alfaro-Shigueto, et al. (2014). "Big catch, little sharks: Insight into Peruvian small-scale longline fisheries." Ecology and Evolution.

Dulvy, N. K., S. L. Fowler, et al. (2014). "Extinction risk and conservation of the world’s sharks and rays." eLife 3:e00590: 1-34.

European Commission (2013). Request for information on long-line catches in West Indian Ocean. D. Standing. Brussels.

FAO (2011). FishStatJ - software for fishery statistical time series, Food and Agriculture Organization of the United Nations.

Frazier, J. (1980). "Exploitation of Marine Turtles in the Indian Ocean." Human Ecology 8(4): 329-370.

Groombridge, B. and R. Luxmoore (1989). The Green Turtle and Hawksbill (Reptilia: Cheloniidae): World Status, Exploitation and Trade, Secretariat of CITES, Lausanne, Switzerland.

Hughes, G. R. (1974). The status of sea turtles in South East Africa. I. Status, morphology and distributions. Durban, Oceanographic Research Institute: 1-144.

Humber, F. and D. Hykle (2011). Report on the workshop for the adoption of a management and conservation plan for marine turtles in Madagascar. London, Blue Ventures Conservation and IOSEA: 56.

IUCN (2015). IUCN Red List of Threatened Animals, IUCN, Gland and Cambridge.

Jacquet, J., H. Fox, et al. (2010). "Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania." African Journal of Marine Science 32(2): 97-106.

Lagueux, C. J., C. L. Campbell, et al. (2014). "Artisanal Green Turtle, *Chelonia mydas*, Fishery of Caribbean Nicaragua: I. Catch Rates and Trends, 1991–2011." PLoS ONE 9(4): e94667. doi:10.1371/journal.pone.0094667.

Le Manach, F., C. Gough, et al. (2012). "Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar?" Marine Policy 36: 218-225.

Le Manach, F., C. Gough, et al. (2011). Reconstruction of total marine fisheries catches for Madagascar (1950-2008). pp. 21-37. In: Harper, S. and Zeller, D. (eds.) Fisheries catch reconstructions: Islands, Part II. Fisheries Centre Research Reports 19(4). Fisheries Centre, University of British Columbia [ISSN1198-6727].

Lilette, V. (2006). "Mixed results: conservation of the marine turtle and the red-tailed tropicbird by Vezo semi-nomadic fishers." Conservation and Society 4(3): 262–286.

Lilette, V. (2007). Conservation et patrimonialisation de la tortue marine dans le sud-ouest de l'océan Indien Faculté des Lettres et Sciences Humaines, Université de La Réunion: 426.

McVean, A., R. Walker, et al. (2006). "The traditional shark fisheries of southwest Madagascar: A study in the Toliara region." Fisheries Research 82: 280-289.

Milliken, T. and H. Tokunaga (1987). The Japanese Sea Turtle Trade, 1970-1986. A Special Report prepared by TRAFFIC (Japan). Washington D.C, The Center for Environmental Education: 171.

Pascal, B. (2003). Requin et tortues de mer chez les Vezo du Sud-Ouest de Madagascar. Enjeux écologiques ou enjeux sociaux? Orléans, Université d'Orléans: 127.

Pascal, B. (2008). De la « Terre des Ancêtres » aux Territoires des vivants: Les enjeux locaux de la gouvernance sur le littoral sud-ouest de Madagascar Paris, Muséum National d’Histoire Naturelle 420.

Rakotonirina, B. and A. Cooke (1994). "Sea turtles of Madagascar – their status, exploitation and conservation." Oryx 28(1): 51-61.

Robinson, L. and W. H. H. Sauer (2013). "A first description of the artisanal shark fishery in northern Madagascar: implications for management." African Journal of Marine Science 35(1): 9 - 15.

Wayne King, F. (1995). Historical review of the decline of the green turtle and the hawksbill. Biology and Conservation of Sea Turtles. Revised Edition. K. A. Bjorndal. Washington D.C, Smithsonian Institution Press: 183-188.

Wielgus, J., D. Zeller, et al. (2010). "Estimation of fisheries removals and primary economic impact of the small-scale and industrial marine fisheries in Colombia." Marine Policy 34: 506-513.

Wildlife Conservation Society. (2014). "New listing to protect 21 species of sharks and rays."   Retrieved 12th November, 2014, from http://www.sciencedaily.com/releases/2014/11/141110110209.htm.

World Bank/FAO/WorldFish Center (2010). The hidden harvests: the global contribution of capture fisheries. Conference Edition, Washington, DC, USA. Washington DC, Agriculture and Rural Development Department and Sustainable Development Network.

Zeller, D., S. Booth, et al. (2006). "Fisheries Contributions to the Gross Domestic Product: Underestimating Small-scale Fisheries in the Pacific." Marine Resource Economics 21(4): 355-374.

Zeller, D., S. Booth, et al. (2011). "Arctic fisheries catches in Russia, USA, and Canada: baselines for neglected ecosystems." Polar Biology 34: 955–973.

Chapter 1: Using community members to assess artisanal fisheries: the marine turtle fishery in Madagascar

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Abstract

Fisheries are considered a major driver of population declines for many marine vertebrate species, and yet for some, data on the levels of direct catch are lacking, often due to the logistical challenges in assessing artisanal fisheries in remote and developing regions. Using community members to collect data can provide access to a greater wealth of information than that obtained by local or foreign researchers, often at a reduced financial cost. We monitored the harvest of marine turtles at 12 major villages in Madagascar using community members as data collectors (*sous collecteurs*) from each village, at a total cost of <US$3000 for 1 year. Community members were trained to collect biological and fisheries data on turtles landed and to use digital cameras to provide a visual record of each turtle catch recorded. A total of 699 marine turtle landings were documented, including four species, with by far the majority being green turtles *Chelonia mydas* (93.6%). When we contextualize our data with those of previous studies elsewhere in the region, we conservatively estimate that the annual turtle catch in the southwestern province of Madagascar is between 10,000 and 16,000. Although turtle hunting is illegal under national law, there are currently no government initiatives to manage the fishery. This study is the first direct assessment of the level of exploitation of turtles in Madagascar, made possible through the use of community members as data collectors and has broad applicability towards similar data gathering efforts in other artisanal fisheries.

Introduction

Assessing the impact of small-scale or artisanal fisheries can be logistically challenging, especially at remote locations, in developing countries (Salas *et al*., 2007; Soykan *et al*., 2009). While recent studies attempt to quantify the marine turtle bycatch in industrial fisheries, they highlight the lack of available data from small-scale and artisanal fisheries (Lewison & Crowder, 2007; Gilman *et al*., 2010; Wallace *et al*., 2010). Bycatch has been assessed in artisanal fisheries through direct observations (Alfaro-Shigueto *et al*., 2008; Mangel *et al*., 2010) or interview data (D’agrosa, Lennert-Cody & Vidal, 2000; McCluskey & Lewison, 2008; Peckham *et al*., 2008) but can fail to produce quantitative estimations (Moore *et al*., 2010). Direct harvest of marine turtles from artisanal fisheries is rarely quantified and studies often rely on carapace counts (Koch *et al*., 2006; Metcalf *et al*., 2007) or fisher interview data (Rakotonirina & Cooke, 1994; Nichols, 2003).

The remote Toliara region of south-west Madagascar contains some of the most extensive and biodiverse coral habitats in the Indian Ocean, and supports Madagascar’s largest traditional fishery (Laroche & Ramananarivo, 1995; Laroche *et al*., 1997). Artisanal fishing is the primary income source for the indigenous Vezo coastal communities, but a recent dramatic increase in fishing intensity has led to direct reef damage and concerns of unsustainable biomass removal (Laroche *et al*., 1997; Gabrié *et al*., 2000). In the Toliara region, the fishing population has increased by at least a factor of five over a period of 17 years and is still growing through migration of inland populations to coastal regions (Cooke, Lutjeharms & Vasseur, 2003).

As a result of numerous threats, all species of marine turtle have experienced population declines and are included on the IUCN Red List of threatened species (IUCN, 2010). In Madagascar, all species of marine turtle are protected from domestic exploitation (Presidential Decree 2006–400); however, fishers continue to actively harvest and consume all five species of marine turtle found in these waters (Ratsimbazafy, 2003; Epps, 2006). The laws are not enforced due to several factors, including a lack of capacity for implementation, a reluctance to manage a fishery with strong cultural links and the immensity of the Malagasy coastline (Rakotonirina & Cooke, 1994; Okemwa, Muthiga & Mueni, 2005).

The majority of turtles landed are caught through targeted fishing, using nets, spearguns or a specialized harpoon, '*Teza*' or '*Nato*' (Astuti, 1995; Ratsimbazafy, 2003; Gough *et al*., 2009). Turtle hunting is considered an important cultural Vezo activity and has several associated ancestral rituals (Astuti, 1995; Ratsimbazafy, 2003). Traditionally, turtle fishers had several restrictions that they had to observe, in particular in relation to the preparation of the meat. While some fishers still observe the traditions or parts of them, there has been a relaxation of these cultural practices, especially where new capture methods have been used (Hughes, 1970; Astuti, 1995; Lilette, 2006; Pascal, 2008).

There is a paucity of thorough assessments of the directed fishery of turtles in Madagascar. From interviews and observations, Hughes (1971) estimated that the annual turtle catch from south-west Madagascar was >13,000, and Frazier (1980) extrapolated these data to produce an annual catch of 13,856 for the whole of Madagascar. More recent studies using interviews estimate the annual marine turtle catch in Madagascar to be 11,000–12,000 (Rakotonirina & Cooke, 1994; Walker, Roberts & Fanning, 2004; Walker & Roberts, 2005).

The lack of reliable, up-to-date data on the current status of turtle populations throughout Madagascar has been noted as a barrier to the creation of viable management plans for conservation (Shanker & Pilcher, 2003; Shanker, 2004; Kimakwa *et al*., 2008). In October 2006, a marine turtle research and conservation programme in the Andavadoaka region of Madagascar was initiated using community members to record marine turtle catch to ascertain landing rates, record information on fishing methods and gauge whether community members can act as reliable data collectors. In this paper, we report on a year of data collected on the current status and local perceptions of the traditional turtle fishery, its context within previous regional assessments, and offer management recommendations for the future.

Methods

Study area

The study was conducted in the region surrounding the village of Andavadoaka (22^{o}04’19.94’’S, 43^{o}14’20.00’’S) in southwest Madagascar, c. 150 km north of Toliara, the regional capital. The area is characterized by two distinct fringing and barrier reef systems separated by a 5-km-wide passage or channel in which several patch reefs are situated. The coastal villages are almost entirely composed of Vezo fishers. All fishing is carried out using pirogues (small sailing canoes) or walking with nets, lines or spears, limiting most fishing effort to the nearby reef systems, with fishing at deeper, offshore sites only possible under favourable sea conditions.

The monitoring programme

To develop a profile of the turtle fishery in the region, a monitoring programme was established in October 2006 that employed local community members as data collectors, known as ‘*sous-collecteurs*’, in each of the villages in the study. Village presidents, elders or their wives were normally chosen as their approval was needed to run this study in their village, and they were normally in the best position to enable the monitoring programme to be accepted by the village residents. One community member was employed per village (nine men and four women), apart from Bevato, where two were employed because of the village’s geographical spread.

Initially, 14 villages along the coastline were chosen for the study, spanning c. 60 km of coastline from Antsepoke in the south (22^{o}15’50.14’’S, 43^{o}13’34.80’’E) to Morombe in the north (21^{o}44’44.28’’S, 43^{o}21’43.23’’E; Fig. 1). No villages refused to participate in this study, although two villages were removed from the study after a few months due to the difficulty in locating suitable community members to collect data (Nosy Mitata and Nosy Ve). The 12 final study villages were chosen to encompass the majority of fishers and the population in general (54% of villages and an estimated 87% of regional population and >70% of fishers).

Community members were paid a base monthly salary of 15 000 Malagasy Ariary (MGA) (≈US$8) and an additional 300 MGA (≈US$0.16) for each landed turtle they recorded. The average daily wage in the region is <US$2 and this payment acted to supplement their normal income. The 300 MGA was intended to be given to the fisher as a gift for allowing their turtle to be measured. It was agreed during initial talks with fishers that this was a fair price and that the price per catch was high enough to encourage people to visit the community members but low enough so as not to encourage additional turtle fishing. In larger villages and towns, where there is a greater demand for turtle meat, turtle merchants now exist who will buy turtles from fishers for ≈ 50 000–140 000MGA (≈US$24–66), depending on the turtle’s size, to sell in the local market (Pascal, 2003; Walker *et al*., 2004; Lilette, 2007).

Data collection

Each community member data collector was trained by the Project Coordinator and Malagasy assistant to record biological data, fisher demographics and catch-specific information for each turtle in the initial training session (≈1 h) in their village. They were also trained to use a digital camera to record catch in order to check the reliability of the data and reduce the possibility of falsified data. For each turtle landed, biological data: species, curved carapace length (CCL) and sex (if possible), and fisheries data: method of capture and name of fisher(s), were recorded.

Community members were given notebooks, containing identification charts and diagrams of measurements and tape measures. Vezo fishers are familiar with each of the five marine turtle species that occur in the region and each has their own name in the regional dialect of Malagasy (Table 2).

Community members were visited every two months by the Project Coordinator and Assistant in order to retrieve the data and review data collection methods. Further training with the camera was given if photos were not of high enough quality. The Project Coordinator was responsible for collating and verifying all data collected. Any unreadable data were removed. Data were entered into an excel spreadsheet and cross referenced with the original data sheet. Photographs were checked for species ID with the data in the spreadsheet for each community member. The camera’s memory cards were cleared after each data collection visit to ensure that accidental replication of photos could not occur.

In order to conduct an overview of the turtle fishery from the villagers’ perspectives, semi-structured interviews, lasting approximately 1 h, were carried out with the community member data collectors in each village between October and December 2007. The interview consisted of 14 questions aimed at providing background information regarding the context of the fishery in the region and report changes in turtle size or number caught. Interviews were conducted in Malagasy by the Project Coordinator and Assistant. The nature and sensitivity of this study meant that we did not record interviews and opted for a qualitative approach, avoiding detailed interviewing of large numbers of fishers in case it would interfere with general catch reporting.

Results

Four villages were unable to record landed turtles in every month for varying reasons. The community member data collector from Belavenoke migrated after 3 months and a suitable replacement was not found. The first 7 months of data from Nosy Hao were not considered reliable after inconsistencies were spotted between the data book and the digital camera records. A new data collector was then hired. The monitoring programmes in Morombe and Nosy Lava were not initiated until February and March 2007, respectively, due to the distance between these villages and the research centre at Andavadoaka. Table 1 shows the list of villages included in this study, their population size and the number of months they recorded turtle catch between 1 January 2007 and 31 December 2007.

The total cost of this monitoring effort was <US$3000, which includes the cost of community member payments, equipment, a Malagasy research assistant and travel between villages. A total of 699 landed turtles were recorded in the 12 villages in this study (Fig. 1, Table 1). The potential number of turtles landed in the region accounting for missing months of data is estimated conservatively as 817 (Table 1). For those villages that did not record a full 12 months of landings, absolute numbers of recorded turtles were extrapolated to estimate 12 months of landings using the mean of the recorded monthly data. These figures are likely to be the minimum turtle landings for each village as all community members noted that they were not able to record every landed turtle. Because of problems with understanding the concept of percentages, community members were unable to estimate the proportion of landed turtles that were missed in order to allow us to correct annual catches for each village.

The majority of turtles recorded were green turtles *Chelonia mydas* (93.6%; Table 2), while the second most commonly recorded species, the hawksbill turtle, *Eretmochelys imbricata* only accounted for 3.4% of the recorded landings. From a subset of captures, species proportions discernible from photo data (n=269) correlated well with other records (Table 2). No landings of leatherback turtles, *Dermochelys coriacea*, were recorded during this study.

Interviews with the data collectors reported that bycatch of turtles in nets laid out for pelagic species, such as sharks, was almost negligible in the traditional fishery, and six reported that there were no occupational turtle fishers in their village. However, the results showed that some fishers were likely to be targeting turtles. Of a total of 132 fishers who were linked with reported captures, nine fishers accounted for 20.6% (n=144) of the turtles recorded in the study. The town of Morombe recorded 25% of turtle landings in this study and has the largest human population (≈12,000). The trend to use nets to catch turtles extends throughout the study villages, and in total, 68% of turtles recorded were caught using the jarifa net (12–25 cm mesh gill net); 17% used a spear or harpoon, of which 0.7% used the traditional turtle spear. The ZDZD (8–10 cm mesh gill net) was recorded in 5% of landings. The remaining 9.1% of landings recorded less specific methods or materials and 0.4% of landings had no method recorded. Further data gathered on fishing sites are not presented here but will be utilized in regional management plans.

The number of turtles recorded per month remained fairly consistent over the year (Fig. 2), barring a marked peak in November 2007. Interviews with community members revealed that the austral summer, November to February, is cited as the best season to catch turtles but is also the period most susceptible to bad weather, which can reduce fishing intensity.

The size class distribution of the green turtles (n=644) landed is shown in Fig. 3. CCL ranged from 21 to 120 cm, with 96–100 cm being the dominant size class. There was no significant difference in the mean CCL of green turtles by month (one-way ANOVA, F11, 643=1.47, P40.05). Previous studies have recorded a minimum size of nesting females of 85 cm (CCL) in Madagascar (Metcalf *et al*., 2007; Alisson, 2008); thus, as much as 36% (n=233) of green turtles recorded in our study could have been mature individuals. Three individuals were confirmed adult females from distant nesting sites; two had been tagged at nesting beaches in Europa and one in Mayotte, all over 90 cm CCL. Sex cannot be definitively determined visually in all subadult turtles but of the adult-sized individuals at least 74 (32.0%) were identified as male through observation of a sexually dimorphic tail length.

The size distribution of hawksbill turtles was strongly skewed towards smaller individuals, with 41–45 cm being the dominant size class (Fig. 3). With a minimum size for nesting conspecifics being 58 cm CCL (Hughes, 1974a; Alisson, 2008), at least 79.2% of recorded hawksbills in this study were juveniles.

The results of the informal interview regarding the status of turtle stocks were equivocal. Although five of the 12 community members reported that either the number and/or the size of turtles captured had decreased in the last 5–20 years

(Table 3), five reported that there had been no change in the turtle numbers and two reported an increase in the numbers of turtles landed. The reason given for the latter were the introduction of new fishing methods in Nosy Be, while in Morombe, the community member suggested that fewer fishers were targeting turtles because they were aware of the law against hunting.

The province of Toliara, with a coastline of 1180 km covering the whole of the southwest of Madagascar, is home to the majority of the Vezo fishing communities (Rakotonirina & Cooke, 1994).We now have a robust yet conservative estimate of the number of turtle captures in our study region in one year (817 turtles per 60km). If we assume a similar catch rate per km of coastline for this region, we estimate the total harvest for the Toliara region to be 16,000 per annum. Alternatively, if we estimate catch based on the annual estimated harvest from five previous studies (d–h) encompassing 204 km (17.3%) of the Toliara coastline totalling 1707 turtles (Fig. 4, Table 4), our estimate is closer to 10,000 turtles per annum. Our overall estimate of 10,000–16,000 turtles per annum is for the Toliara region alone, and although this is thought to be the major region for turtle fishing in Madagascar, other regions have also recorded significant levels of harvest (studies a–c; Fig. 4, Table 4) and therefore the annual catch for Madagascar is likely to be much greater.

Discussion

This paper describes a cost-efficient method working with community members to directly measure marine turtle harvest. A severe deficit of research and monitoring of the turtle fishery are regularly cited as problems in regional conservation meetings (IUCN, 1996; Mortimer, 2002; Okemwa *et al*., 2005; Kimakwa *et al*., 2008). It has broad replicability for increasing data available from any smallscale or artisanal fishery. Monitoring species' populations can be time-consuming and expensive and developing countries require alternative methods (Danielsen, Burgess & Balmford, 2005; Holck, 2008; Danielsen *et al*., 2009). If properly designed, local participatory monitoring can yield reliable results comparable to professional monitoring, in addition to being low cost, fast, locally and nationally relevant, and become a cost-effective long term monitoring tool (Danielsen *et al*., 2005; Holck, 2008). However, participatory methods can also play an important role in building community capacity, responsibility and ownership through the development of a greater understanding of local problems (Fazey *et al*., 2010).

The approach used in this study was not without limitations (Table 5), in particular, the restriction of the level of in-depth data collection and locating suitable data collectors who were able to assimilate the methods quickly without a formal education or monitoring experience. The reliability of these data was increased through verification from the digital camera records and a local field assistant. Despite problems with the quality of photos of individual turtles, the cameras did play an important role in preventing cheating and to support the data collected. For obvious species, such as marine turtles, studies such as these are likely to provide a more robust assessment of a fishery than through fisher interviews alone. Future studies would benefit from additional data using an alternative method to determine harvest rates in order to provide a direct comparison of the effectiveness of community data collectors.

In 1980, estimates of turtle catch in Madagascar were over 13,000 turtles per annum (Hughes, 1971; Frazier, 1980). By 1992, Rakotonirina & Cooke (1994) estimated the nationwide harvest as 11,000 per annum. After two decades, our study estimates that the current annual turtle landings by artisanal fishers for the Toliara region alone, which likely represents the majority of the national harvest, are still of the same magnitude, if not higher. We base these estimates on limited field studies and there is clearly an urgent need to further assess the level of harvest around the country and move towards promoting sustainability, perhaps through the introduction of legal harvest quota through an exemption to the law for traditional use.

There are few long-term data from Madagascar but it is widely believed that the country's in-water turtle populations are declining (Okemwa *et al*., 2005). Anecdotal reports of diminishing catches over the previous decade (Walker & Roberts, 2005) are not indicated from harvest and interview data but were supported at a regional workshop held in 2009 by turtle fishers and community data collectors. There are several reasons why captures may have remained high.

Firstly, the Vezo pride themselves on their innovative fishing methods and the *jarifa* nets originally designed for shark fishing, introduced in the 1990s (Langley, 2006), are now also used to catch turtles. A relaxation in the ancestral rituals associated with turtle fishing has allowed the Vezo to take advantage of these easier methods of turtle hunting, which may make effort more effective (Astuti, 1995; Pascal, 2003; Walker & Roberts, 2005; Lilette, 2007). This has been coupled by an increase in coastal human populations, degradation of marine resources and the desire for greater material wealth, leading to hunting turtles to sell at markets, an act once considered a taboo, and the development of merchants specializing in buying and selling turtle meat (Pascal, 2003, 2008; Lilette, 2006, 2007). Hunting turtles to sell for profit now drives the majority of the fishery, especially for villages close to the larger markets of Toliara and Morombe (Pascal, 2003; Lilette, 2007), where turtles fetch a high price in comparison with other marine resources.

The high number of green turtles landed and yet the apparent low level of nesting in Madagascar (Rakotonirina, Razafinjara & Harding, 2004; Walker & Roberts, 2005; Metcalf *et al*., 2007) strongly indicates that the majority of turtles landed originate from source populations elsewhere in the western Indian Ocean. Tagging studies have shown that the waters of Madagascar provide important feeding grounds for juvenile and adult turtles from nesting populations located throughout the western Indian Ocean, including the Îles Éparses, Seychelles and mainland Africa (Hughes, 1974b; Limpus *et al*., 2001; Rakotonirina *et al*., 2004; Lauret-Stepler *et al*., 2007; Metcalf *et al*., 2007).

Although Seminoff (2004) reported that there had been a 32% reduction in green turtle nesting populations compared with historic levels in the western Indian Ocean, recent estimates show significant increases in track counts on Europa (3% increase year^{-1}) and Grande Glorieuse (6% increase year^{-1}) over the last 20 years, strongly suggesting that populations visiting these islands have increased (Lauret-Stepler *et al*., 2007). The numbers have remained stable in Mayotte (Bourjea *et al*., 2007). It may be that increased recruitment from such populations is subsidizing the turtle fishery in Madagascar.

Despite the recent increases in nesting, it is possible that the impacts of the turtle fishery in Madagascar and elsewhere in the region have been impeding population recovery over the past decades or their impacts may yet be revealed as a result of the slow life history of green turtles. Bourjea *et al*. (2007) speculate that the green turtle is not endangered in the region and is capable of supporting the current exploitation levels. Concern should, however, be raised regarding the trajectory of fishing pressure on turtle populations in Malagasy waters, in both the magnitude and the method, given extant patterns of degradation of marine resources and coastal population growth (UNEP *et al*., 1998; Institut National de la Statistique & ORC Macro, 2005; Ahamada *et al*., 2008; Harris *et al*., 2010).

Conservation efforts within Madagascar have included the protection of some nesting sites and work on reducing bycatch through the installation of Turtle Excluder Devices to trawlers (Okemwa *et al*., 2005; Kimakwa *et al*., 2008). Bycatch is seen as one of the major global factors in marine turtle mortality and is the focus, along with its mitigation, of a large volume of scientific literature (Gilman *et al*., 2006, 2010; Lewison & Crowder, 2007; Tomás *et al*., 2008; Murray, 2009). This study highlights that direct turtle harvest in artisanal fisheries also needs to be addressed. There is also a need to monitor breeding turtle populations in Madagascar in order to assess and clarify current population status (Table 3).

However, there have been few turtle conservation measures aimed at or working with the artisanal fishing communities in Madagascar, and those that have, have had limited success due to political crises and a lack of adherence (Gladstone, Andriantahina & Soafiavy, 2003; Walker & Roberts, 2005). Our study has shown that the numbers of turtles caught within a small human population can be substantial over a year but effective management is not likely to occur without community approval. The recent meeting of the Western Indian Ocean Marine Turtle Task Force (Kimakwa *et al*., 2008) highlighted the fact that Madagascar ‘has a strong community incentive for turtle conservation…the system embraces the community structure – employing traditions, culture and customs’. Other countries have fisheries management policies that have taken into account traditional turtle fisheries and, although regulated, allowed them to remain intact (Bell *et al*., 2007).

This study reflects the extent of the artisanal turtle fishery in Madagascar and the need for increased marine turtle conservation efforts and assessments of direct fisheries harvest. It provides a cost- and time-efficient method for gathering data from artisanal fisheries and provides a system of collecting data that could help answer priority conservation research questions highlighted recently in Hamann *et al*. (2010). If research is conducted ethically and through the development of trusted relationships within the community, it may foster greater community ownership of resources (Fazey *et al*., 2010) and increase the chance of the development of accepted conservation measures, which will also allow for a greater chance of success through compliance and self-regulation (Silver & Campbell, 2005; Shackeroff & Campbell, 2007).

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References

Ahamada, S., Bijoux, J., Cauvin, B., Hagan, A. B., Harris, A., Koonjul, M., Meunier, S. & Quod, J.-P. (2008). Status of the Coral Reefs of the South-West Indian Ocean Island State: Comoros, Madagascar, Mauritius, Reunion, Seychelles. In *Status of the Coral Reefs of the World*: 73-79. Wilkinson, C. R. (Ed). Australian Institute of Marine Science, Townsville, Australia.

Alfaro-Shigueto, J., Mangel, J. C., Seminoff, J. A. & Dutton, P. H. (2008). Demography of loggerhead turtles *Caretta caretta* in the southeastern Pacific Ocean: fisheries-based observations and implications for management. *Endang. Species Res.* **5,** 129–135.

Alisson, G. (2008). *De le ponte à l'éclosion: Suivi de la reproduction de deux espèces menacées de tortues marines, la tortue verte et la tortue imbriquée, sur l'île de Nosy Iranja, Madagascar.* Masters thesis, Université La Réunion, La Réunion.

Andriamalala, G. (2008). *Évaluation socio-économique de base de l’Aire Protégée communautaire Velondriake, sud-ouest de Madagascar*. London: Blue Ventures Conservation.

Andriamiseza, O., Rakotomavo, H. & Rakotonirina, B. (2006). *FAO Workshop: Assessing the Relative Importance of Sea Turtle Mortality due to Fisheries*.). Madagascar Report, Zanzibar.

Astuti, R. (1995). *People of the sea: Identity and descent among the Vezo of Madagascar*. Cambridge: Cambridge University Press.

Bell, C., Solomon, J., Blumenthal, J., Austin, T., Ebanks-Petrie, G., Broderick, A. & Godley, B. (2007). Monitoring and conservation of critically reduced marine turtle nesting populations: lessons from the Cayman Islands. *Anim. Conserv.* **10,** 39-47.

Bourjea, J., Frappier, J., Quillard, M., Ciccione, S., Roos, D., Hughes, G. & Grizel, H. (2007). Mayotte Island: another important green turtle nesting site in the southwest Indian Ocean. *Endang. Species Res.* **3,** 273–282.

Cooke, A., Lutjeharms, J. & Vasseur, P. (2003). Marine and coastal ecosystems. In: *The natural history of Madagascar*: 179-209. Goodman, S. & Benstead, J. (Eds). Chicago: Chicago University Press.

D’agrosa, C., Lennert-Cody, C. E. & Vidal, O. (2000). Vaquita bycatch in Mexico’s artisanal gillnet fisheries: driving a small population to extinction. *Conserv. Biol.* **14,** 1110–1119.

Danielsen, F., Burgess, N. D. & Balmford, A. (2005). Monitoring matters: examining the potential of locally-based approaches. *Biodivers. Conserv.* **14,** 2507–2542.

Danielsen, F., Burgess, N. D., Balmford, A., Donald, P. F., Funder, M., Jones, J. P. G., Alviola, P., Balete, D. S., Blomley, T., Brashares, J., Child, B., Enghoff, M., Fjeldså, J., Holt, S., Hübertz, H., Jensen, A. E., Jensen, P. M., Massao, J., Mendoza, M. M., Ngaga, Y., Poulsen, M. K., Rueda, R., Sam, M., Skielboe, T., Stuart-Hill, G., Topp-Jørgensen, E. & Yonten, D. (2009). Local participation in natural resource monitoring: a characterization of approaches. *Conserv. Biol.* **23,** 31-42.

Epps, M. (2006). *A Socioeconomic Baseline Assessment: Implementing the socioeconomic monitoring guidelines in southwest Madagascar*. 78pp. London: Blue Ventures Conservation.

Fazey, I., Kesby, M., Evely, A., Latham, I., Wagatora, D., Hagasua, J.-E., Reed, M. S. & Christie, M. (2010). A three-tiered approach to participatory vulnerability assessment in the Solomon Islands. *Global Environ. Change.* (Online DOI: 10.1016/j.gloenreha.2010.04.011).

Frazier, J. (1980). Exploitation of Marine Turtles in the Indian Ocean. *Hum. Ecol.* **8,** 329-370.

Gabrié, C., Vasseur, P., Randriamiarana, H., Maharavo, J. & Mara, E. (2000). The coral reefs of Madagascar. In: *Coral Reefs of the Indian Ocean*: 411-444. Mcclanahan, T., Sheppard, C. & Obura, D. (Eds). New York: Oxford University Press.

Gilman, E., Zollett, E., Beverly, S., Nakano, H., Davis, K., Shiode, D., Dalzell, P. & Kinan, I. (2006). Reducing sea turtle by-catch in pelagic longline fisheries. *Fish Fish.* **7,** 2–23.

Gilman, E., Gearhart, J., Price, B., Eckert, S., Milliken, H., Wang, J., Swimmer, Y., Shiode, D., Abe, O., Peckham, S. H., Chaloupka, M., Hall, M., Mangel, J., Alfaro Shigueto, J., Dalzell, P. & Ishizaki, A. (2010). Mitigating sea turtle by-catch in coastal passive net fisheries. *Fish Fish.* **11,** 57–88.

Gladstone, N., Andriantahina, F. & Soafiavy, B. (2003). *Azafady Project Fanomena – Marine Turtle Conservation and Research in Southeast Madagascar*. Report on Activities and Findings in the 2001-2002 Nesting Season.75pp. London: Azafady.

Gough, C., Thomas, T., Humber, F., Harris, A., Cripps, G. & Peabody, S. (2009). *Vezo Fishing: An introduction to the methods used by fishers in Andavadoaka, Southwest Madagascar*. 37pp. London: Blue Ventures Conservation.

Hamann, M., Godfrey, M. H., Seminoff, J. A., Arthur, K., Barata, P. C. R., Bjorndal, K. A., Bolten, A. B., Broderick, A. C., Campbell, L. M., Carreras, C., Casale, P., Chaloupka, M., Chan, S. K. F., Coyne, M. S., Crowder, L. B., Diez, C. E., Dutton, P. H., Epperly, S. P., Fitzsimmons, N. N., Formia, A., Girondot, M., Hays, G. C., Jiunn, C. I., Kaska, Y., Lewison, R., Mortimer, J. A., Nichols, W. J., Reina, R. D., Shanker, K., Spotila, J. R., Tomás, J., Wallace, B. P., Work, T. M., Zbinden, J. & Godley, B. J. (2010). Global research priorities for sea turtles: informing management and conservation in the 21st century. *Endang. Species Res.* **11,** 245–269.

Harris, A., Manahira, G., Sheppard, A., Gough, C. & Sheppard, C. (2010). Demise of Madagascar's once great barrier reef - change in coral reef condition over 40 years. *Atoll Res. Bull.* **574**, 1-16.

Holck, M. H. (2008). Participatory forest monitoring: an assessment of the accuracy of simple cost–effective methods. *Biodivers. Conserv.* **17,** 2023–2036.

Hughes, G. R. (1970). Preliminary report to the Southern African Wildlife Foundation (World Wildlife Fund) on the status of sea turtles in south east Africa. Section 2: Madagascar and the Mascarene. 1-47 + 6 pp Appendices. Oceanographic Research Institute, Durban.

Hughes, G. R. (1971). Sea turtle research and conservation in South East Africa. *Proceedings of the 2nd working meeting of marine turtle specialists*: 57-67. International Union for the Conservation of Nature and Natural Resources. Supplementary Papers, No 31, Morges.

Hughes, G. R. (1974a). *The status of sea turtles in South East Africa. I. Status, morphology and distributions*. 1-144. Durban: Oceanagraphic Reseach Institute.

Hughes, G. R. (1974b). *The status of sea turtles in South East Africa. II. The biology of the Tongaland Loggerhead Turtle Caretta caretta L. with comments on the Leatherback Turtle Dermochelys coricea L. and the Green Turtle Chelonia mydas L. in the study region*. 1-96. Durban: Oceanagraphic Reseach Institute.

Institut National de la Statistique (INSTAT) [Madagascar] & ORC Macro. (2005). Enquête Démographique et de Santé, Madagascar 2003–2004: Rapport de synthèse. INSTAT and ORC Macro, Calverton.

IUCN (1996). *A Marine Turtle Conservation Strategy and Action Plan for the Western Indian Ocean.* Nairobi: International Union for the Conservation of Nature and Natural Resources.

IUCN (2010) *2010 IUCN Red List of Threatened Animals*. Gland: IUCN.

Kimakwa, E., Ngusaru, A., Hykle, D. & Nel, R. (2008). *Report of the First Meeting of the Western Indian Ocean – Marine Turtle Task Force (WIO-MTTF).* United Republic of Tanzania: Dar es Salaam.

Koch, V., Nichols, W. J., Peckham, H. & Toba, V. D. L. (2006). Estimates of sea turtle mortality from poaching and bycatch in Bahía Magdalena, Baja California Sur, Mexico. *Biol. Conserv.* **128,** 327 – 334.

Langley, J. (2006). *Vezo Knowledge: Traditional Ecological Knowledge in Andavadoaka, southwest Madagascar*. London: Blue Ventures Conservation.

Laroche, J. & Ramananarivo, N. (1995). A preliminary survey of the artisanal fishery on coral reefs of the Tulear region (southwest Madagascar). *Coral Reefs.* **14,** 193-200.

Laroche, J., Razanoelisoa, J., Fauroux, E. & Rabenevanana, M. (1997). The reef fisheries surrounding the south-west coastal cities of Madagascar. *Fish. Manag. Ecol.* **4,** 285-299.

Lauret-Stepler, M., Bourjea, J., Roos, D., Pelletier, D., Ryan, P., Ciccione, S. & Grizel, H. (2007). Reproductive seasonality and trend of *Chelonia mydas* in the SW Indian Ocean: a 20 yr study based on track counts. *Endang. Species Res.* **3,** 217-227.

Lewison, R. & Crowder, L. B. (2007). Putting Longline Bycatch of Sea Turtles into Perspective. *Conserv. Biol.* **21,** 79–86.

Lilette, V. (2006). Mixed results: conservation of the marine turtle and the red-tailed tropicbird by Vezo semi-nomadic fishers. *Conservat. Soc.* **4,** 262–286.

Lilette, V. (2007). *Conservation et patrimonialisation de la tortue marine dans le sud-ouest de l'océan Indien.* PhD thesis, Université de La Réunion, La Réunion.

Limpus, C. J., Al-Ghais, S. M., Mortimer, J. A. & Pilcher, N. J. (2001). *Marine turtles in the Indian Ocean and Southeast Asian region: Breeding, distribution, migration and population trends*. Convention on Migratory Species.

Mangel, J. C., Alfaro-Shigueto, J., Van Waerebeek, K., Cáceres, C., Bearhop, S., Witt, M. & Godley, B. J. (2010). Small cetacean captures in Peruvian artisanal fisheries: High despite protective legislation. *Biol. Conserv.* **143,** 136–143.

Mccluskey, S. M. & Lewison, R. (2008). A synthesis of current fishing effort estimation methods and their application. *Fish Fish.* **9,** 188–200.

Metcalf, J., Hampson, K., Andriamizava, A., Andrianirina, R., Cairnes, T., Gray, A., Ramiarisoa, C. & Sondotra, H. (2007). The importance of north-west Madagascar for marine turtle conservation. *Oryx.* **41,** 232-238.

Moore, J. E., Cox, T. M., Lewison, R. L., Read, A. J., Bjorkland, R., Mcdonald, S. L., Crowder, L. B., Aruna, E., Ayissi, I., Espeut, P., Joynson-Hicks, C., Pilcher, N. J., Poonian, C. N. S., Solarin, B. & Kiszka, J. (2010). An interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries. *Biol. Conserv.* **143,** 795–805.

Mortimer, J. (2002). *A Strategy to Conserve and Manage the Sea Turtle Resources of the Western Indian Ocean Region.* Report produced for IUCN, WWF and the Ocean Conservancy.

Murray, K. T. (2009). Characteristics and magnitude of sea turtle bycatch in US mid-Atlantic gillnet gear. *Endang. Species Res.* **8,** 211–224.

Nichols, W. J. (2003). *Biology and conservation of sea turtles in Baja California, Mexico*. PhD thesis, University of Arizona, Tucson.

Okemwa, G., Muthiga, N. & Mueni, E. (2005). *Proceedings of the Western Indian Ocean Region Marine Turtle Conservation Workshop*. September 16-17, 2004, Mombasa, Kenya, 26pp.

Pascal, B. (2003). *Requin et tortues de mer chez les Vezo du Sud-Ouest de Madagascar. Enjeux écologiques ou enjeux sociaux?* Mémoire de DEA, Université d'Orléans, Orléans.

Pascal, B. (2008). *De la « Terre des Ancêtres » aux Territoires des vivants: Les enjeux locaux de la gouvernance sur le littoral sud-ouest de Madagascar*. PhD thesis, Muséum National d'Histoire Naturelle.

Peckham, S. H., Maldonado-Diaz, D., Koch, V., Mancini, A., Gaos, A., Tinker, M. T. & Nichols, W. J. (2008). High mortality of loggerhead turtles due to bycatch, human consumption and strandings at Baja California Sur, Mexico, 2003 to 2007. *Endangered Species Research.* **5,** 171–183.

Rakotonirina, B. & Cooke, A. (1994). Sea turtles of Madagascar – their status, exploitation and conservation. *Oryx.* **28,** 51-61.

Rakotonirina, B., Razafinjara, A. & Harding, S. (2004). Madagascar Status Report. In *Proceedings of the Western Indian Ocean Marine Turtle Conservation Workshop*. Okemwa, G., Muthiga, N. & Mueni, E. (Eds). Mombasa, Kenya.

Ratsimbazafy, R. (2003). Sea Turtles. In *The natural history of Madagascar*: 210-213. Goodman, S. & Benstead, J. (Eds). Chicago: Chicago University Press.

Salas, S., Chuenpagdee, R., Seijo, J. C. & Charles, A. (2007). Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. *Fish. Res.* **87,** 5–16.

Seminoff, J. A. (2004). *MTSG global assessment of green turtles (Chelonia mydas) for the IUCN Red List*. Gland: IUCN Species Survival Commission. Available at: www.iucn-mtsg.org/red_list/cm/MTSG_chelonia_mydas_assessment_april-2004.pdf

Shackeroff, J. & Campbell, L. (2007). Traditional Ecological Knowledge in Conservation Research: Problems and Prospects for their Constructive Engagement. *Conservat. Soc.* **5,** 343-360.

Shanker, K. (2004). Marine turtle status and conservation in the Indian Ocean. *Papers presented at the expert consultation on interactions between sea turtles and fisheries within an ecosystem context, Rome, 9-12 March 2004, FAO Fisheries Report No. 738*. FAO, Rome, 238pp.

Shanker, K. & Pilcher, N. J. (2003). Marine Turtle Conservation in South and Southeast Asia: Hopeless Cause or Cause for Hope? *Mar. Turtle Newsl.* **100,** 43-51.

Silver, J. & Campbell, L. (2005). Fisher participation in research: Dilemmas with the use of fisher knowledge. *Ocean Coast. Manage.* **48,** 721-741.

Soykan, C. U., Moore, J. E., Žydelis, R., Crowder, L. B., Safina, C. & Lewison, R. L. (2009). Why study bycatch? An introduction to the Theme Section on fisheries bycatch. *Endangered Species Research.* **5,** 91–102.

Tomás, J., Gozalbes, P., Raga, J. A. & Godley, B. J. (2008). Bycatch of loggerhead sea turtles: insights from 14 years of stranding data. *Endangered Species Research.* **5,** 161–169.

UNEP, Institute of Sciences, University of Dar es Salaam., FAO & SIDA (1998). Overview of land-based sources and activities affecting marine, coastal and associated freshwater environment in the eastern African region. UNEP Regional Seas Reports and Studies No. 167. UNEP, Nariobi.

Walker, R. & Roberts, E. (2005). Marine Turtles of South West Madagascar. *Western Indian Ocean J. Mar. Sci.* **4,** 219-225.

Walker, R., Roberts, E. & Fanning, E. (2004). The Trade of Marine Turtles in the Toliara Region, South West Madagascar. *Mar. Turtle Newslett.* **106,** 7-9.

Wallace, B. P., Lewison, R., Mcdonald, S. L., Mcdonald, R. K., Kot, C. Y., Kelez, S., Bjorkland, R. K., Finkbeiner, E. M., Helmbrecht, S. R. & Crowder, L. B. (2010). Global patterns of marine turtle bycatch. *Conserv. Lett.* **3**, 1–12.

Table 1. The 12 villages included in the monitoring programme, their population size and the number of months in 2007 during which landed turtles were recorded. The estimated number of turtles landed shows the total if villages had recorded for 12 months. Human population data were from 2006 and 2008 (Epps, 2006; Andriamalala, 2008).

Village	**Human population**	**No. months monitoring**	**No. turtles recorded**	**Estimated annual landings**
Morombe	12 000[a]	11	179	195
Nosy Lava	350[a]	10	56	67
Nosy Be	523	12	168	168
Bevato	472	12	91	91
Belavenoke	429	3	23	92
Andranombala	109	12	22	22
Andavadoaka	1 220	12	59	59
Nosy Hao	259	5	16	38
Ampasilava	321	12	27	27
Lamboara	506	12	13	13
Ankitambagna	86	12	34	34
Antsepoke	270[a]	12	11	11
Total			**699**	**817**

[a] Estimation by Blue Ventures; no official survey conducted.

Table 2. Breakdown of species of marine turtle landings recorded (1 January–31 December 2007) with the mean curved carapace length (CCL) and capture method for each species, including loggerhead *Caretta caretta* and olive ridley *Lepidochelys olivacea*. No leatherback turtles (Malagasy name: Fano valorozo) were recorded.

Species of turtle (Malagasy name)	**No. Recorded (% overall)**	**No. recorded in subset of 269 photos (%)**	**CCL (cm)**		**No. caught by *jarifa* net (%)**	**No. caught by spear or harpoon (%)**	**No. caught by ZDZD (%)**	**No. caught by other/ unidentified methods (%)**
			Mean and SD	**Range**				
Loggerhead (Fano apombo)	11 (1.6)	3 (1.1)	74.4 ± 20.2	40-98	9 (81.8)	0 (0)	2 (18.2)	0 (0)
Green (Fano zaty)	654 (93.6)	169 (62.8)	74.4 ± 22.1	21-120	451 (69.1)	110 (16.8)	33 (5.1)	60 (9.0)
Hawksbill (Fano hara)	24 (3.4)	2 (0.7)	50.6 ± 15.5	31-89	7 (29.2)	13 (54.2)	0 (0)	4 (16.6)
Olive Ridley (Fano tsakoy/ tsipioke)	3 (0.4)	1 (0.4)	66.0 ± 14.7	57-83	1 (33.3)	0 (0)	0 (0)	2 (66.7)
Unidentified	7 (1.0)	94 (35.0)	NA		3 (42.9)	3 (42.9)	0 (0)	1 (14.2)

Table 3. Community member data collectors' attitudes to changes in the turtle fishery.

Village	Have you noticed a change in the size, species or number of turtles captured?			
	Yes or No	If yes: specify if it's been an 'increase' or 'decrease', the order of size if possible and the time period over which this change has occurred.		
Ampasilava	Yes	Decrease	Numbers caught	Last 5 years
Andavadoaka	Yes	Decrease	In size	Last 10 years
Andranombala	Yes	Decrease	Numbers caught	Last 20 years
Ankitambagna	No			
Antsepoke	No			
Belavenoke	No			
Bevato	No			
Lamboara	No			
Morombe	Yes	Increase	Numbers caught	Last 5 years
Nosy Be	Yes	Increase	Numbers caught	None given
Nosy Hao	Yes	Decrease	Numbers caught	Last 10 years
Nosy Lava	Yes	Decrease	Numbers caught and size	Last 20 years

Table 4. The potential number of turtles landed in artisanal fisheries from data from previous studies.

Study label on Fig.4	**Location of study**	**Estimated / Recorded turtle landings**	**Length of data collection**	**How was data collected**	**Estimated number per year**	**Reference**
a	Antsiranana	129	4 months in 2000	Unknown	387	Sodontra, 2003 (in Andriamiseza *et al.,* 2006)
b	Nosy Hara	380	July to December 2000	Count of Carapaces	760	Metcalf *et al.*, 2007
b	Nosy Iranja	9	July to December 2000	Count of Carapaces	18	Metcalf *et al.*, 2007
b	Radama Islands	63	July to December 2000	Count of Carapaces	126	Metcalf *et al.*, 2007
c	Illes Barren	30	2008	Pers. Comm.	30	Géraud Leroux pers. comm.
d	Morombe to Antsepoke	699	January to December 2007	Direct count of landings	817	This study (see Table 1)
e	Beravy-Ifaty	165	June 2008 to June 2009	Direct count of landings	165	Reefdoctor (unpublished data)
f	Toliara	279	10 months 1989	Market Surveys	335	Rakotonirina & Cooke, 1994
g	Anakao to Ambola	501 (per month in peak season)	2002	Fisher Interviews	2991	Walker & Roberts, 2005
h	96 km of coastline north of Tolagnaro	63	15 Nov 2001 - 27 Feb 27 2002	Port surveys/ market surveys	252	Gladstone *et al.*, 2003
Total		**2318**			**5881**	

Table 5. Limitations and recommendations for implementing community data collection of turtle harvest.

Limitations	Recommendations
Low levels of education and literacy	Ensure monitoring materials are as clear and simple as possible, with the inclusion of diagrams. Repeat training on a regular basis.
Locating suitable community date collectors e.g. due to jealousy within a village	Create a trial period for initial data collection and remove the village and choose another location if problems can not be resolved.
Fishers wary of reporting their ‘illegal’ turtle landings	Choose community data members that have standing in the village; Hold village meetings to explain the aim of the monitoring.
Unable to use a digital camera	Purchase simple cameras and dedicate enough time to camera training at the start of the study.
No formal training in research methods	Ensure monitoring equipment is as simple as possible to reduce likelihood of errors eg mark the correct side of the measuring tape to use.
Varied use of local names for fishing sites and fishing methods (and potentially species)	Use participatory methods to create maps/lists of agreed local names.
Number of monitoring variables limited	Highlight the most important aim of the research and be aware to not over burden data collectors with too many monitoring questions.
Problems with understanding concept of percentages	Monitoring questions focussing on increases or decreases in populations or harvests may need to use qualitative descriptions to ascertain changes from interviews.

Figure 1. Map showing the location of the 12 villages included in this study and the number of landed turtles recorded. The inset shows the location in Madagascar.

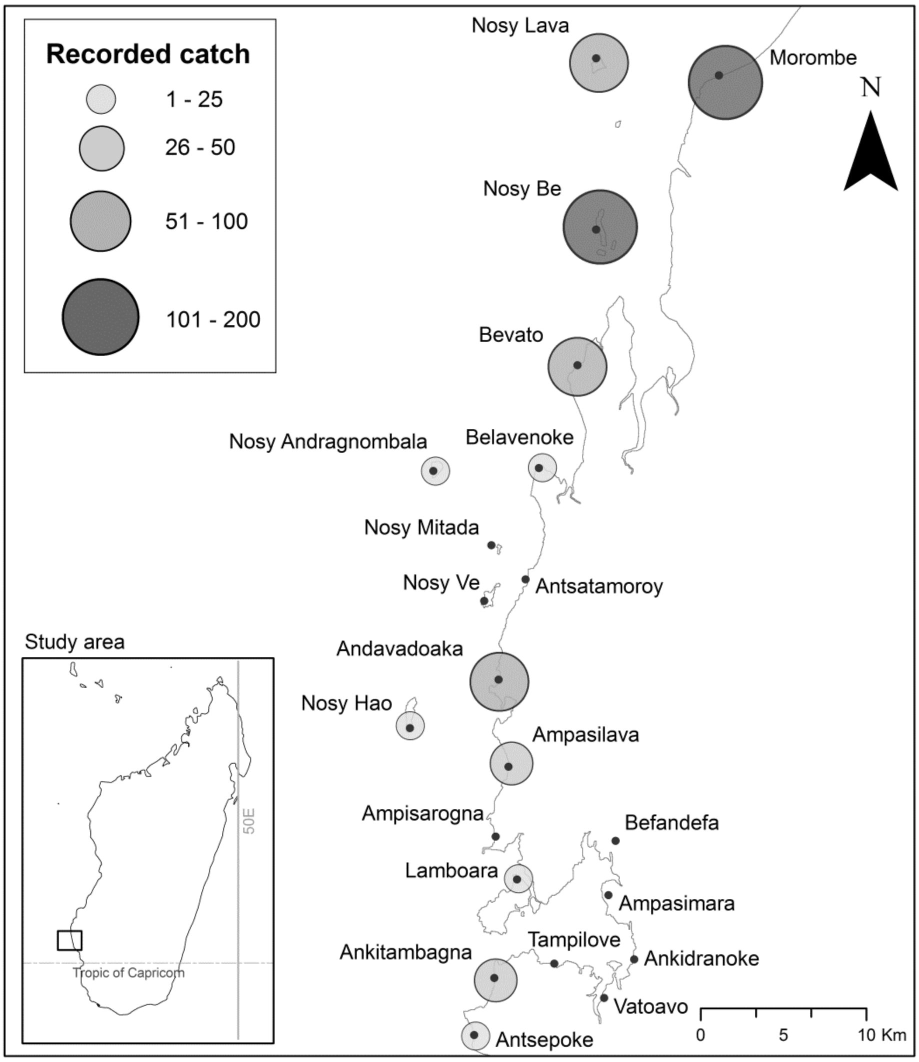


Figure 2. Total turtle landings from 1 January to 31 December 2007 for villages that recorded a full year of data. Data from the villages of Morombe, Nosy Lava, Belavenoke and Nosy Hao have been removed.

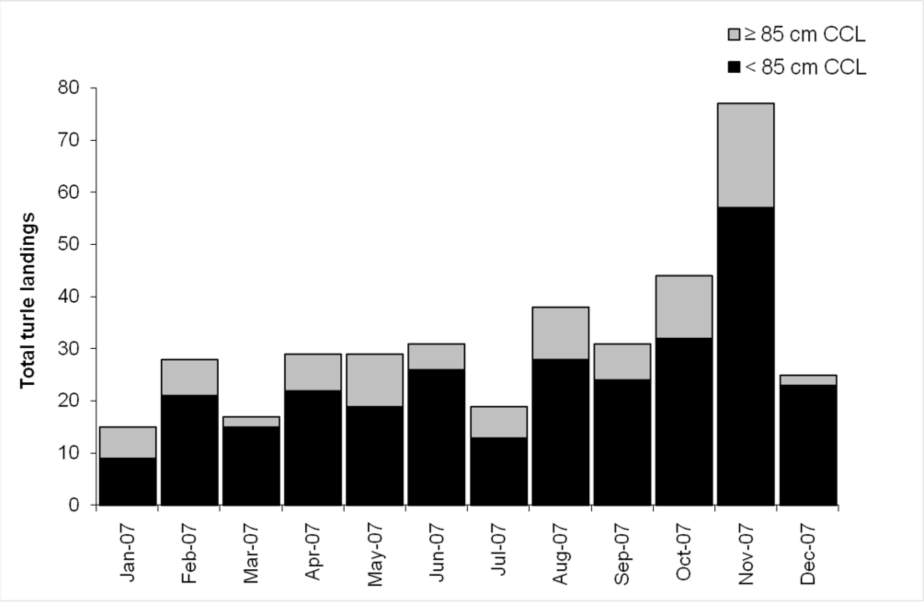


Figure 3. Curved carapace length of green and hawksbill turtles recorded in this study (1 January–31 December 2007). The percentage of potential juveniles and adults at minimum sizes of recorded nesting green (Metcalf et al., 2007) and hawksbill (Alisson, 2008) turtles are shown on the graph.

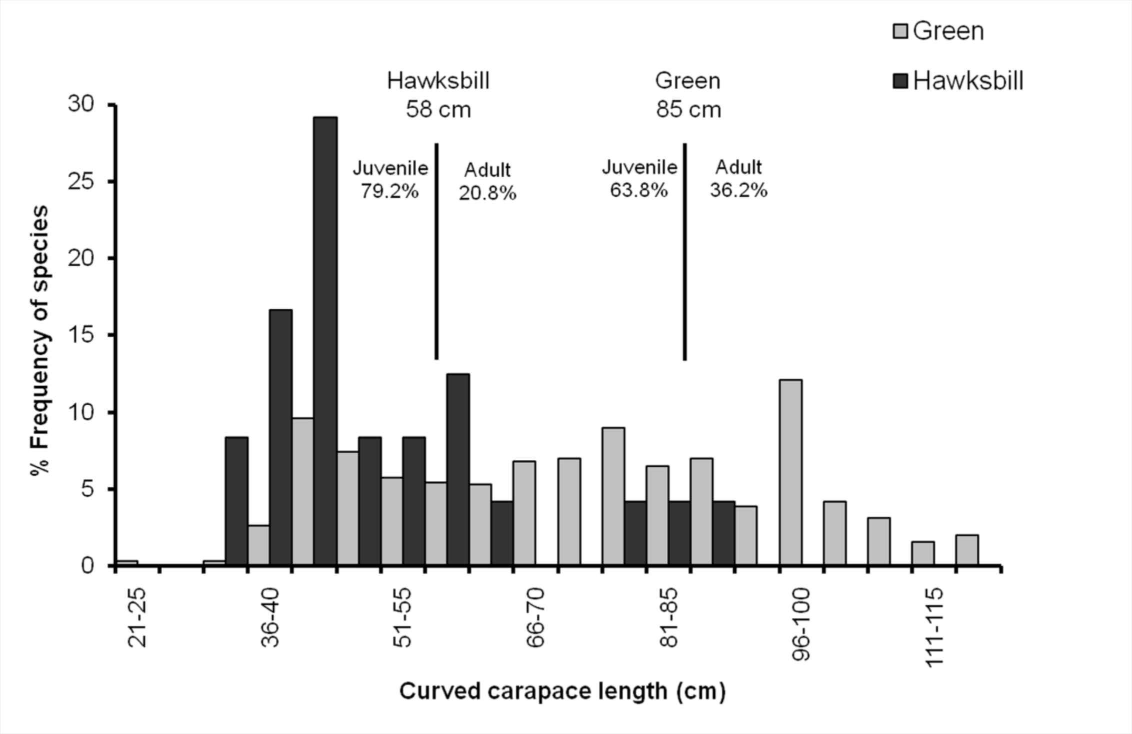
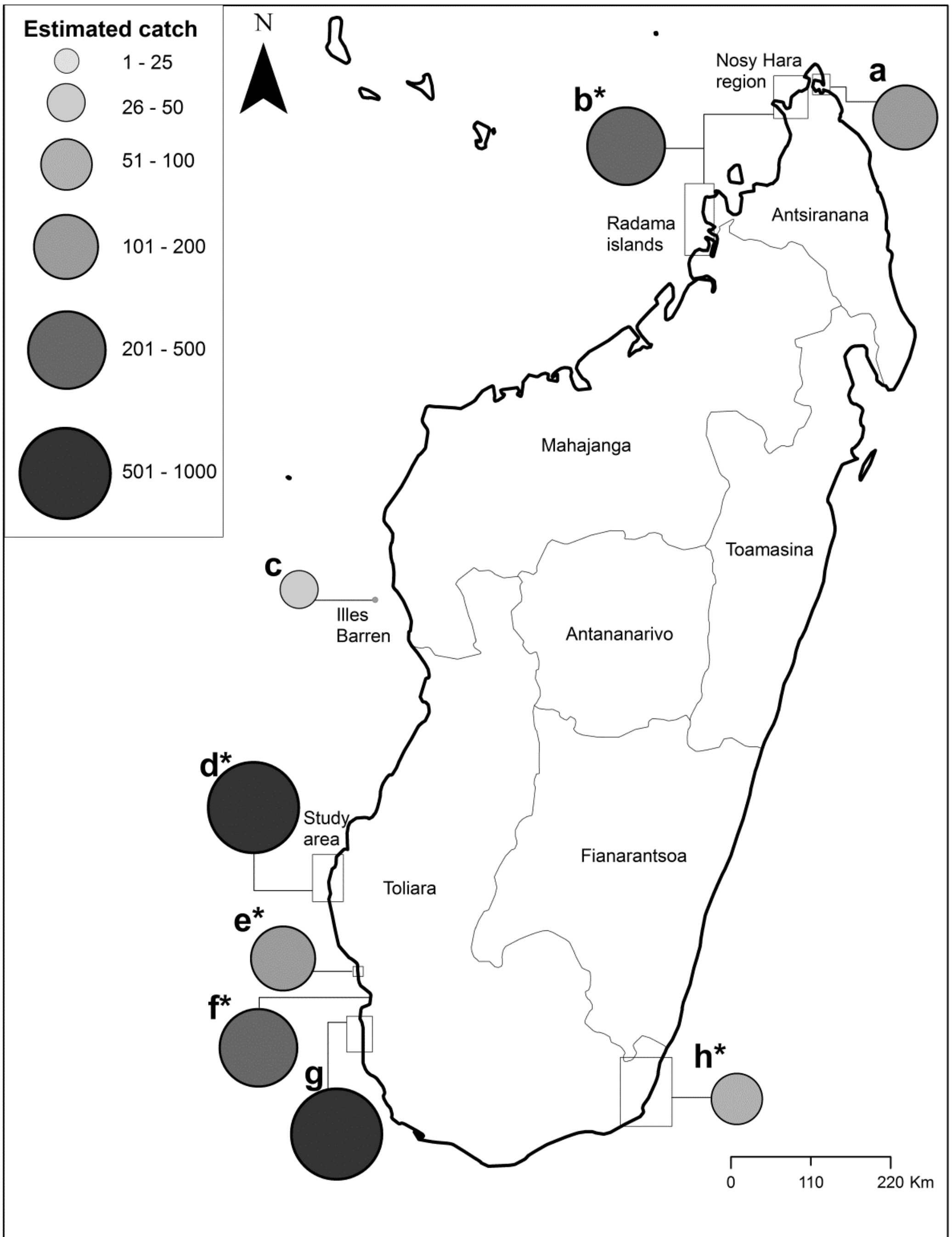


Figure 4. Map showing the location of previous studies on the traditional turtle fishery in Madagascar, the study site (d) and the numbers of turtles estimated in each study. Lengths of boxes are scaled to show the approximate lengths of the coastline covered by the study. *Turtle catch estimated through actual count of landed turtles or carapaces.



a: Sodontra, 2003 (in Andriamiseza *et al.*, 2006)
b: Metcalf *et al.*, 2007
c: Géraud Leroux pers. comm.
d: This study (see Table 1)
e: Reefdoctor (unpublished data)
f: Rakotonirina & Cooke, 1994
g: Walker & Roberts, 2005
h: Gladstone *et al.*, 2003

Chapter 2. So excellent a fishe: a global overview of legal marine turtle fisheries

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Abstract

Aim We provide a global assessment of the current legal direct take of marine turtles, including the scale and species breakdown at country level, and investigate the significance of legal take to marine turtle populations within the wider context of global threats.

Location World-wide.

Methods We undertook a comprehensive review of the literature (> 500 publications) and contacted over 150 in-country experts to collate data for countries that permit the legal take of marine turtles (as of 1 January 2013). Current annual take for each country and species was estimated, and estimates were generated for the 1980s, 1990s and 2000s.

Results Currently, 42 countries and territories permit direct take of turtles and collectively take in excess of 42,000 turtles per year, the majority of which (> 80%) are green turtles Chelonia mydas (Linnaeus 1758). Ten countries account for more than 90% of legal take each year with Papua New Guinea (36.1%) and Nicaragua (22.3%) accounting for more than half of the total global take. Since 1980, we estimate that more than 2 million turtles have been legally taken in these countries, with current levels < 60% of those in the 1980s.

Main conclusions Our results provide the most comprehensive global synthesis of the legal take of turtles in recent years and suggest that legal take has the potential to be a driver of marine turtle population dynamics, comparable to mortality estimates through recorded bycatch. However, it is

likely that illegal take, along with bycatch, is significantly under-recorded and far greater than the total level of directed legal take. This hampers the ability to assess the relative impacts of these threats to marine turtles.

Introduction

Widescale commercial exploitation is thought to have contributed significantly to the global decline in marine turtle populations (Lewis, 1940; Stoddart, 1980; Jackson, 1997; National Marine Fisheries Service & U.S. Fish and Wildlife Service, 1998; Broderick et al., 2006; Cornelius et al., 2007) leaving many populations at relictual levels (Pritchard, 2003; McClenachan et al., 2006; Bell et al., 2007). However, the direct take of nesting and foraging marine turtles for meat, shell and other products has taken place for millennia (Groombridge & Luxmoore, 1989; Frazier, 2003; Daley et al., 2008). Artisanal and subsistence take, as part of longstanding traditional fisheries, primarily for local consumption, may historically have been at more sustainable levels (Frazier, 1980), but levels of exploitation increased radically upon western colonization of the New World (Babcock, 1938; Wayne King, 1995; Mrosovsky, 1996). Quickly, some of this take proved unsustainable, with the first marine turtle harvest legislation instigated in Bermuda in 1620 to protect '..so excellente a fishe..', prohibiting taking any turtle 'under Eighteen inches in the Breadth or Dyameter' (Babcock, 1938; Godley et al., 2004).

Notwithstanding, large-scale commercial take in areas with remaining abundance continued, with global capture peaking at over 17,000 tonnes in the late 1960s (FAO, 2011), principally fuelled by commercial-scale exploitation and international trade (Fleming, 2001; van Dijk & Shepherd, 2004). For example, during the peak of Mexico's sea turtle exploitation in 1968, it is estimated that the national take was over 380,000 turtles (Cantú & Sanchez, 1999). The continued international trade of turtle products in the latter half of the 20th century meant that over 2 million turtles (hawksbill *Eretmochelys imbricata*, Linnaeus 1766; green *Chelonia mydas* and olive ridleys *Lepidochelys olivacea*, Eschscholtz, 1829) would have been needed to produce the volume of marine turtle products imported into Japan between 1970 and 1986 (Milliken & Tokunaga, 1987). Against the backdrop of widespread commercial exploitation, a decline in traditional and small-scale turtle fisheries also occurred (Frazier, 1980; Allen, 2007; Bell et al., 2010), resulting from increased pressures from human populations and more efficient capture methods (Brikke, 2009), often with a corresponding breakdown of associated cultural rituals that would have once promoted more sustainable take levels (Hickey, 2003; Allen, 2007).

Increased conservation awareness at the international scale has led to greater protection of marine turtles and a series of multilateral agreements with associated enabling local legislation coming into force to restrict the trade of turtle products, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1975, which helped to reduce demand and promote regional cooperation in increasing turtle populations. By 1980, 59 countries were signatories to CITES rising to 178 in 2013, and although subject to considerable debate, marine turtle species have been listed on the IUCN Red List of Threatened Species since 1982 (Mrosovsky, 2003; IUCN, 2013).

Despite increasing levels of protection, the direct take of turtles has continued legally in many regions and countries (Bräutigam & Eckert, 2006; Aylesworth, 2009; Maison et al., 2010). Permitted take now tends to be characterized by subsistence use by traditional coastal groups, or small-scale fisheries supplying local markets with meat, and sometimes shell (Bräutigam & Eckert, 2006;

Limpus, 2008; Maison et al., 2010). The fisheries continue to be an important source of finance, protein and cultural identity in these parts of the world (Hamann et al., 2006; Vander Velde, 2008). Although the nature of these permitted fisheries vary greatly among countries and regions, many have been subject to increasing regulations over the past 30 years, with specific legislation put in place to help manage direct take, often limiting species, number, timing or size of turtles targeted (Bräutigam & Eckert, 2006). There is, however, a paucity of information on the direct take from these fisheries at present, despite often being listed as one of the major threats to marine turtle populations (Wallace et al., 2010; IUCN, 2013). Here, we set out to assess the current legal direct take (hereafter referred to as legal take) of marine turtles globally; as well as recent trends within those countries.

Methods

Focal countries

In this study, we focussed on coastal countries or territories, hereafter referred to as countries, which currently (as of 1 January 2013) permit the legal take of marine turtles and are geographically between 40°N and 40°S. This region covers the majority of the known range of hard-shelled marine turtle species (IUCN, 2013). Although some marine turtle species can occur outside this range, there is no significant direct turtle take documented outside these latitudes. Legalized egg harvest was not included in this study.

The national legislation within these countries was further classified as allowing marine turtle take if protection was absent, unverifiable, incomplete or temporary. National legislation was classified into one of five categories: protection absent (N), legislation allows for a level of directed take of one or more species of turtles (L), full protection but traditional hunting exemptions exist (T), moratorium in place at present (M) and unable to verify legislation (U).

Data compilation

We searched relevant databases (e.g. Web of Knowledge, Google Scholar, seaturtle.org, Sea Turtle Bibliography at the Archie Carr Center for Sea Turtle Research, SPC Coastal Fisheries Programme) and the broader internet using combinations of relevant keywords (‘turtle’ with ‘take’, ‘harvest’ or ‘fishery’). Over 500 reports and papers were collated and reviewed to compile data on legal take, with bycatch or incidental take data removed where possible. In the first instance, data from actual studies were prioritized, but in the absence of such data estimates by experts found in the literature or via personal communications were used. Where data presented in the literature were unclear or incomplete, efforts were made to consult relevant authors. Further consultation with expert individuals living in or known to work in target nations (> 150 contacted by email; 106 responded with information) was undertaken to locate further reports and papers and ascertain best estimates of legal take since 1 January 2010.

Data for all seven species of marine turtles (green; hawksbill; loggerhead *Caretta caretta*, Linnaeus 1758; olive ridley; leatherback *Dermochelys coriacea*, Vandelli 1761; Kemp's ridley *Lepidochelys kempii*, Garman 1880; flatback turtle *Natator depressus*, Garman 1880), were collated by country (see Table S1 in Supporting Information; Appendix S1).

A median was calculated for any estimates given as ranges. Where a single estimate was provided as an annual estimate for a number of years, the same value was used for each year in the range. Estimates given as a total figure for a number of years were divided equally among those years. Multiple estimates by different authors for the same year were averaged. No attempt was made to extrapolate data where estimates were given for periods less than a year, or when they were not countrywide estimates. In these cases, values were included as minimum values.

In a small number of highlighted cases (Table S1; n = 8), international trade statistics in bekko (hawksbill turtle shell) were used to calculate estimates for hawksbills, only where no other data could be located. Conversions rates of bekko (kg) to number of turtles were normally given by authors (e.g. Fiji 0.7–1.1 kg bekko/turtle, Milliken & Tokunaga, 1987).

Creating annual estimates for each decade

We calculated the median annual take for each decade (1980s, 1990s and 2000s) for each species by country and for our current estimate the median annual take for the years 2010–2012.

Data that had not been identified by species were only included in circumstances where we were confident that the data were not duplicated within other studies. Data were then broken down into species using the best available species composition information from additional studies and reports from that country.

Where data were missing for a decade, we used the temporally closest data to extrapolate. For example, where we only had data for the 1990s and 2000s, we used the 1990s estimate for the 1980s. Where decadal data were only available for the 1980s and 2000s (*n* = 4 countries), we used what we considered would be the most similar estimate for the 1990s, in relation to any changes in legislation or reports of increases/decreases in legal take. Where data for only one decade existed (*n* = 8 countries), this was used for all other decades. To allow confidence to be assigned to overall estimates, any ‘estimated’ data are highlighted.

Current take

Relevant expert individuals contacted between 2011 and 2013 were also asked for comments on present-day harvest compared with the last known study or report on take within a country. If the expert was unable to answer or unable to confirm, then take was assumed to have been unchanged from the most recent known estimate.

Results

Legislation

As of 1 January 2013, a total of 42 countries permitted the direct take of marine turtles, four countries had a moratorium on take (Anguilla, Chile, Fiji and the Maldives), although permits for traditional purposes can be granted in Fiji; and four countries had legislation that could not be verified (Algeria, North Korea, Panama and Somalia) (Fig. 1) (see Table S1 for information on type or absence of legislation). A change of legislation to prohibit direct turtle take occurred in three countries (Republic of Congo, South Korea and Trinidad and Tobago) between 1 January 2010 and 1 January 2013. Data from these countries, and also those that prohibited turtle take between 1980 and 2010, are not included in this study.

Take by species

We estimate that currently, more than 42,000 marine turtles are caught each year as legal take (*n* = 42 countries). Over 80% of these are green turtles (37,339; 88.5% of catch), with an estimated 3456 hawksbill turtles taken each year (8.2%) (Fig. 2). Fewer than 1500 loggerhead (1051; 2.5%), leatherback (62; 0.1%) and olive ridley (263; 0.6%) turtles are estimated to be among those legally captured each year. Data on take of flatback turtles were scarce with only a small amount recorded from Papua New Guinea and Australia, approximately 18 turtles year^{-1} (Kare, 1995; Kennett et al., 1998). No data were found on legal take of Kemp's ridley turtles from 1980 to present day.

Green turtles were the only species permitted to be taken from all countries within this study, with the exception of countries with a moratorium (although not including Fiji). Leatherbacks had the highest degree of protection and were prohibited from take in 13 of the 42 focal countries examined (31%).

Global distribution of take

Current permitted take is concentrated in two regions: the wider Caribbean region accounts for 34.6% (14,640 turtles year^{-1}) of estimated take from 16 countries (see inset Figs 3 & 4a) and the Indo-Pacific region accounts for 63.3% (26,675 turtles year^{-1}) from 17 countries (Figs 3 & 4b). No take was known to occur in four of the countries where it was legal (Bosnia and Herzegovina, Niue, Pitcairn Islands and Wallis and Futuna). In 12 countries, take was unquantified: in three of these countries, take was known to occur but no estimate was available (Kiribati, Nauru and Syria), and nine of these countries only illegal take data were found (Belize, Cayman Islands, Dominica, Indonesia and Atlantic coast of Mexico), including four countries where a moratorium exists (Anguilla, Chile, Fiji and Maldives). Take from the four countries where legislation could not be verified (Algeria, North Korea, Panama and Somalia) is estimated to be 6700 turtles year^{-1} and is not included in the 42,000 estimate (Table S1). A breakdown of take by species for each country is available in Figures S2, S3 and Table S1.

Take by country

The top ten countries with permitted take account for 94.2% (39,716) of marine turtle take per year (Fig. 5). Papua New Guinea (15,217 turtles year^{-1}; 36.1%), Nicaragua (9413 turtles Year^{-1}; 22.3%) and Australia (6638 turtles year^{-1}; 15.7%) together account for almost three-quarters of current permitted take (74.1%; 31,268). Given the preponderance of green turtles, the top ten countries for this species are similar to those for overall take. Papua New Guinea, Australia and Nicaragua do not feature in the top countries for the other four species, apart from a small annual take of hawksbills from Papua New Guinea and Australia and a small annual take of loggerheads from Australia (Figure S4).

Past take

The estimated change in annual permitted take of marine turtles in 46 countries that currently allow take of turtles (including the four with current moratoria) over the past 3 decades is illustrated in Fig. 6 and by species in Figure S1. We estimate that more than 2 million turtles have been taken by these countries since 1980. Take has decreased by more than 60% over the past three decades, from an estimated take of 116,420 turtles year^{-1} in the 1980s, 68,844 turtles year^{-1} in the 1990s and 45,387 in the 2000s with this downward trajectory apparently continuing.

One of the major changes in species taken over the past three decades has been in the cessation of the olive ridley take on the Pacific coast of Colombia from nearly 40,000 turtles year^{-1} in the early 1980s to fewer than ten per year in the 1990s and 2000s (Figure S1c). There have also been declines in the other four prevalent species since the 1980s within these countries. There has been a > 40% decline in green take since the 1980s, a > 60% decline in hawksbill and leatherback take and a > 30% decline in loggerhead take.

Although it has not been possible to fully separate all legal and illegal take from data from these countries, there is also some illegal take recorded (see Table

S1; see Appendix S1). It is estimated that currently some additional 13,900 turtles are illegally taken in these 46 countries each year. Within this study, the Pacific coast of Mexico accounts for the current greatest proportion of recorded illegal take with 47.8% (6644 turtles year^{-1}), followed by Indonesia (23.6%; 3279 turtles year^{-1}) and Fiji (23.4%; 3261 turtles year^{-1}) (see Table S1).

Discussion

This study provides the first global synthesis of the reported legal direct take of marine turtles. Our estimate of current legal take, in excess of 42,000 turtles year^{-1}, highlights this as a potential threat to at least some marine turtle populations, but also places this threat in the context of others such as bycatch, that is likely to have a greater impact on global stocks. Our study also shows that there has been a 60% decrease in take from the countries within this study since the 1980s, with further decreases in the global take likely as many countries prohibited take during the period 1980–2010 (e.g. Cuba, Bahamas and Barbados) (Bräutigam & Eckert, 2006). Many green turtle populations, the most heavily targeted species, have also shown large increases in nesting populations in recent decades (Broderick et al., 2006; Chaloupka et al., 2008), potentially facilitated through the reduction or cessation in global take at these sites.

Bycatch estimates for marine turtles have been the focus of a number of relatively comprehensive studies in recent years. Wallace et al. (2010) estimated a minimum global bycatch of 85,000 turtles between 1990 and 2008 but suggest that this likely underestimates the true total by at least two orders of magnitude (due to < 1% fishing effort observed and recorded and underrepresentation of small-scale fisheries in bycatch data). For instance, more recent work by Casale (2011) estimated that there were 44,000 incidental sea turtles deaths year^{-1} alone in the Mediterranean whilst Mancini et al. (2011) estimated that there were > 1000 deaths year^{-1} within one fishery in a lagoon in NW Mexico. Small-scale fisheries in Peru capture tens of thousands of turtles as bycatch annually (Alfaro-Shigueto et al., 2011). These few estimates alone strongly suggest that global mortality from bycatch greatly exceeds that of legal take and likely extends into hundreds of thousands per annum. Improvements have been made in some areas, however, with comparative declines (~60%) in bycatch reported since 1990 in US fisheries (Finkbeiner et al., 2011).

Illegal fishing for turtles also continues to be a major cause of mortality, both in countries within this study and those where take is illegal (Bräutigam & Eckert, 2006; Maison et al., 2010; Lam et al., 2011). We estimate that a minimum of 65,000 turtles have been taken illegally from Mexico since 2000 (Koch et al., 2006; Peckham et al., 2008; Mancini et al., 2011), and in Nicaragua, there is documented take of species other than the permitted green turtles (Lagueux et al., 2003). The scale of global illegal take is likely to be severely underreported due to the inherent difficulty in collecting data on such activity. However, a number of reports highlight widespread artisanal fisheries taking thousands of turtles per years across Africa (WWF, 2005; Peñate et al., 2007; Catry et al., 2009; Marco et al., 2010; Humber et al., 2011). Elsewhere, several medium-sized illegal turtle fisheries are found in the Caribbean (1000–2500 individuals year^{-1}), in Venezuela (Bräutigam & Eckert, 2006), Dominican Republic (Fleming, 2001) and Puerto Rico (Moore et al., 2003), whilst a black market still exists within the Mediterranean for turtle meat (Nada & Casale, 2008).

The majority of current legal take is of green turtles, although past take of olive ridley turtles was significant, there has been a substantial decline in the legal take of both species since 1980s. There has also been a corresponding increase in national legislation during this time that focuses on protecting turtles during breeding seasons whilst allowing customary and traditional users to continue fishing, and is likely a reason for the decline in take over the past 30 years.

The majority of countries with legal turtle take is located in small island states in the Caribbean and Pacific (Melanesia, Polynesia and Micronesia). Turtle take in the Caribbean tends to be legislated through closed seasons, size restrictions by species, permits and gear restrictions (Richardson et al., 2006), whereas turtle take in the Pacific is characterized by high cultural significance with associated customs (Rudrud et al., 2007; Bell et al., 2010; Rudrud, 2010). Both regions report declines in take over the last 30 years (Eckert et al., 1992; Fleming, 2001), in some cases due to a lack of interest from younger generations (e.g. Belize: Bräutigam & Eckert, 2006; British Virgin Islands: S. Davies pers. comm.; Cook Islands: M. White pers. comm.; Samoa: J. Ward pers. comm.; Tokelau: F. Tulafono pers. comm).

However, the three largest legal fisheries persist in Papua New Guinea, in the waters of Australia and on the Atlantic coast of Nicaragua. Estimates used in this study for Nicaragua are, however, based on data from the 1990s, although current levels of take have decreased since last published estimates (C. Lagueux pers. comm.). There are also complications when estimating take for Papua New Guinea and Australia because the majority of turtle take is centred in remote areas of both countries. Furthermore, turtles are taken across the jurisdictions of Australia and Papua New Guinea by Australian Aboriginal and Torres Strait Islanders, as well as the coastal communities in Papua New Guinea and Indonesia. Estimates for the Torres Strait region (includes Torres Strait Islanders and neighbouring Papua New Guinea communities) in the past have been highly variable, from 5100 to 6700 (Kwan, 1991) to 10,000 per year (Limpus, 1980). This study estimates that the take from the whole of Papua New Guinea and Australia is in the order of 20,000 turtles per annum. However, there are limitations to these data from Australia due to the fact that they have been extrapolated from small data sets with restricted spatial and temporal limitations, and there are known large variations in numbers of nesting turtles each year (Limpus, 2008). Results of recent Australian Government supported community-based management programmes, and bilateral Australia and Papua New Guinea projects are also not yet available (Kennett & Kitchens, 2009; Australian Government, 2013).

Although the level of legal take is likely to be relatively low compared with the combined threats of bycatch and illegal take, the existence of a legal fishery has been suggested as providing cover for continued illegal take of turtles (Pritchard, 2003; Reuter & Allan, 2006). Direct take can be more targeted than other causes of marine turtle mortality, often focusing on nesting females (Catry et al., 2009; Marco et al., 2010), and although many countries within this study prohibit the take of nesting turtles, small numbers of adults can represent a large percentage of the nesting population (Limpus et al., 2006; Harris & George, 2008). The impact of direct take can be worsened if high levels of take coincide with the breeding season (Martin et al., 2005; Bell et al., 2007). The migratory nature of turtles also means that otherwise protected nesting populations can be heavily exploited in nearby countries, such as foraging adult females in Nicaragua from the largest green turtle rookery in Tortugeuro, Costa Rica (Campbell, 2003).

There were several difficulties in assessing the status of legal take, most notably the lack of data across many countries and species. Few fisheries departments contacted had any official data available, and in one country contacted data collection had lapsed unnoticed for 3–4 years. A lack of national level monitoring programmes meant that many estimates were based on local studies by research institutions or NGOs, with temporally sporadic data collection (Broderick, 1998; Havea & MacKay, 2009), often generating conservative estimates (Godley et al., 2004).Within our study, original research data were used where possible although in certain instances national estimates by authors as part of reports (e.g. Kinch, 2002) or personal communications were used (e.g. Albania: M. White).

A decline in available papers, reports and official fisheries statistics on legal take in recent years led to an increase in the proportion of estimated data from the 1980s to present day. Many of the current legal turtle fisheries are at the subsistence level or part of small-scale fisheries, which can be difficult to monitor, especially in remote regions in island states (Nichols, 2003; Andrews et al., 2006). Further complications in data collection and analysis can arise in the ambiguity between definitions of direct, opportunistic or incidental take by fishers and researchers (Fuller et al., 1992; Godley et al., 2004). Small-scale and artisanal fishers will often take turtles opportunistically on fishing trips not specifically targeting turtles (Hoyle, 1994; Fleming, 2001; Petro et al., 2007; Alfaro-Shigueto et al., 2011). On top of this, fishing effort can range from specialized dedicated groups, to small numbers of occasional, turtle fishers (Godley et al., 2004), taking turtles both legally and illegally (Aiken et al., 2001; Bräutigam & Eckert, 2006).

Legislation within many countries examined is unclear, and even officials can be operating under false assumptions of the reality of the legislation (Bräutigam & Eckert, 2006). Multiple pieces of legislation within countries have been passed without consulting prior texts for continuity (Bräutigam & Eckert, 2006) or taking into account local stakeholders (Vanuatu: F. Hickey pers. comm.), with frequent changes in restrictions (Caribbean Nicaragua: K. Garland pers. comm.). Many aspects of legislation associated with legal take can be difficult to monitor and enforce, such as restrictions on turtle size and gear types (Buden & Edward, 2001). Furthermore, legislation that allows for subsistence or traditional take can be hard to enforce due to difficulties in definitions; for example, the Nicaraguan green turtle fishery is defined as for subsistence use only but essentially runs at a commercial level (Campbell, 2003).

The debates on the continued legal take of marine turtles span a number of complex issues including ecological principles, human rights and animal welfare (Hamann et al., 2010), and still features in emotionally charged news articles (Holland, 2013). Undoubtedly, bans on large-scale turtle take have helped marine turtle populations to recover (Chaloupka et al., 2008), and current illegal take levels in some countries do not rival those of the previously legal turtle fishery (J. Chevalier in litt. in Bräutigam & Eckert, 2006) or current bycatch (Cornelius et al., 2007). Some countries in this study reported that legal take is declining further (Fiji: M. Raicebe pers. comm.; Cayman Islands: J. Blumenthal pers. comm.).

However, when considering current legal take it should be put in the context of the wider global threats to marine turtles, such as climate change and habitat degradation highlighted as conservation priorities by turtle researchers (Hamann et al., 2010). This study has shown that the relative impact of legal take on mortality could be less than the bycatch estimates from the Mediterranean alone (Casale, 2011). However, further assessments are warranted to understand where conservation priorities should be focussed due to the paucity of up-to-date data on direct take, and a lack of both direct take and bycatch information from small-scale fisheries.

Despite a loss of traditions, turtles remain culturally significant in many countries in this study (especially within Pacific islands), and it is the desire to protect this important cultural resource that has led to control measures on turtle take by governments and traditional authorities (Adams, 2003). Cultural strengthening can play a role in resource management, and the high status awarded to turtles can provide powerful incentives for conservation and management (Hickey & Johannes, 2002; Adams, 2003). Research has indicated that with appropriate management, even depleted populations could recover whilst maintaining a level of take (Chaloupka & Balazs, 2007); although defining what level is sustainable involves a greater knowledge of the threats and links between legal, illegal and bycatch mortality of targeted turtle populations (Hamann et al., 2010).

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References

Adams, T. (2003) *Turtle fisheries in the Pacific Community area*. Marine Resources Division, Secretariat of the Pacific Community, New Caledonia.

Aiken, J.J., Godley, B.J., Broderick, A.C., Austin, T., Ebanks-Petrie, G. & Hays, C.G. (2001) Two hundred years after a commercial marine turtle fishery: the current status of marine turtles nesting in the Cayman Islands. *Oryx*, **35**, 145–151.

Alfaro Shigueto, J., Mangel, J., Bernedo, F., Dutton, P.H., Seminoff, J.A. & Godley, B. (2011) Small-scale fisheries of Peru: a major sink for marine turtles in the Pacific. *Journal of Applied Ecology*, **48**, 1432–1440.

Allen, M.S. (2007) Three millennia of human and sea turtle interactions in Remote Oceania. *Coral Reefs*, **26**, 959–970.

Andrews, H.V., Tripathy, A., Aghue, S., Glen, S., John, S. & Naveen, K. (2006) The status of sea turtle populations in the Andaman and Nicobar Islands of India. *Towards an Integrated and Collaborative Sea Turtle Conservation Programme in India: a UNEP/CMS-IOSEA Project Report* (ed. by K. Shanker and H.V. Andrews), pp. 71-82. Centre for Herpetology/Madras Crocodile Bank Trust, Tamil Nadu.

Australian Government (2013) Traditional Use of Marine Resources Agreements. Available from http://www.gbrmpa.gov.au/our-partners/traditional-owners/traditional-use-of-marine-resources-agreements (accessed July 2013).

Aylesworth, A. (2009) *Oceania regional assessment: Pacific island fisheries and interactions with marine mammals, seabirds, and sea turtles*. Project GloBAL, Beaufort, North Carolina. Available from http://bycatch.env.duke.edu (accessed October 2010).

Babcock, H.L. (1938) The sea-turtles of the Bermuda Islands, with a survey of the present state of the turtle fishing industry. *Proceedings of the Zoological Society of London (A)*, **107**, 595-601.

Bell, C., Solomon, J., Blumenthal, J., Austin, T., Ebanks-Petrie, G., Broderick, A. & Godley, B. (2007) Monitoring and conservation of critically reduced marine turtle nesting populations: lessons from the Cayman Islands. *Animal Conservation*, **10**, 39-47.

Bell, L.A.J., Favae, T.T., Nenenteiti, T.-R., Bebe, R., Anderson, P. & Siota, C. (2010) *Kiribati marine turtles profile*. Secretariat of the Pacific Regional Environment Programme (SPREP), Apia.

Bräutigam, A. & Eckert, K.L. (2006) *Turning the tide: exploitation, trade and management of marine turtles in the Lesser Antilles, Central America, Colombia and Venezuela.* TRAFFIC International, Cambridge, UK.

Brikke, S. (2009) Local perceptions of sea turtles on Bora Bora and Maupiti islands, French Polynesia. *SPC Traditional Marine Resource Management and Knowledge Information Bulletin*, **26**, 23 - 28.

Broderick, D. (1998) *Subsistence hunting of marine turtles in the Solomon Islands. Patterns of resource use in Kia, Wagina and Katupika communities, Isabel and Choiseul Provinces.* Report to the Ministry of Forests, Environment and Conservation and the Ministry of Agriculture and Fisheries, Solomon Island Government.

Broderick, A.C., Frauenstein, R., Glen, F., Hays, G.C., Jackson, A.L., Pelembe, T., Ruxton, G.D. & Godley, B.J. (2006) Are green turtles globally endangered? *Global Ecology and Biogeography*, **15**, 21-26.

Buden, D.W. & Edward, A. (2001) Abundance and Utilization of Sea Turtles on Pohnpei, Federated States of Micronesia: Islanders’ Perceptions. *Micronesica*, **34**, 47–54.

Campbell, C.L. (2003) *Population assessment and management needs of a green turtle, Chelonia mydas, population in the western Caribbean* Doctor of Philosophy, University of Florida.

Cantú, J.C. & Sanchez, M.E. (1999) *Trade in sea turtle products in Mexico*. Teyeliz A.C., Mexico.

Casale, P. (2011) Sea turtle by-catch in the Mediterranean. *Fish and Fisheries*, **12**, 299–316.

Catry, P., Barbosa, C., Paris, B., Indjai, B., Almeida, A., Limoges, B., Silva, C. & Pereira, H. (2009) Status, ecology, and conservation of sea turtles in Guinea-Bissau. *Chelonian Conservation and Biology*, **8**, 150–160.

Chaloupka, M. & Balazs, G.H. (2007) Using Bayesian state-space modelling to assess the recovery and harvest potential of the Hawaiian green sea turtle stock. *Ecological Modelling*, **205**, 93-109.

Chaloupka, M., Bjorndal, K., Balazs, G.H., Bolten, A.B., Ehrhart, L.M., Limpus, C.J., Suganuma, H., Troëng, S. & Yamaguchi, M. (2008) Encouraging outlook for recovery of a once severely exploited marine megaherbivore. *Global Ecology and Biogeography*, **17**, 297–304.

Cornelius, S.E., Arauz, R., Fretey, J., Godfrey, M.H., Márquez-M, R. & Shanker, K. (2007) Effect of land-based harvest of Lepidochelys *Biology and Conservation of Ridley Sea Turtles* (ed. by P.T. Plotkin), pp. 231-251. The Johns Hopkins University Press, Baltimore.

Daley, B., Griggs, P. & Marsh, H. (2008) Exploiting marine wildlife in Queensland: The commercial dugong and marine turtle fisheries, 1847–1969. *Australian Economic History Review*, **48**, 227-265.

van Dijk, P.P. & Shepherd, C.R. (2004) *Shelled out? A Snapshot of bekko trade in selected locations in south-east Asia*. TRAFFIC, Southeast Asia.

Eckert, K.L., Overing, J.A. & Lettsome, B.B. (1992) *WIDECAST Sea Turtle Recovery Action Plan for the British Virgin Islands.* CEP Technical Report No. 15. UNEP Caribbean Environment Programme, Kingston, Jamaica.

FAO (2011) *FishStatJ - software for fishery statistical time series Version 2.0.0*. Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/fishery/statistics/software/fishstatj/en (downloaded 2 March 2013).

Finkbeiner, E.M., Wallace, B.P., Moore, J.E., Lewison, R., Crowder, L.B. & Read, A.J. (2011) Cumulative estimates of sea turtle bycatch and mortality in USA fisheries between 1990 and 2007. *Biological Conservation*, **144**, 2719-2727.

Fleming, E.H. (2001) *Swimming against the tide: Recent surveys of exploitation, trade, and management of marine turtles in the northern Caribbean*. TRAFFIC North America. Washington, D. C.

Frazier, J. (1980) Exploitation of marine turtles in the Indian Ocean. *Human Ecology*, **8**, 329-370.

Frazier, J. (2003) Prehistoric and ancient historic interactions between humans and marine turtles. *The biology of sea turtles, Volume II* (ed. by P.L. Lutz, J.A. Musick and J. Wyneken), Vol. 2, pp. 1– 38. CRC Press, Boca Raton, FL.

Fuller, J.E., Eckert, K.L. & Richardson, J.I. (1992) *WIDECAST Sea Turtle Recovery Action Plan for Antigua and Barbuda*. CEP Technical Report No. 16. UNEP Caribbean Environment Programme, Kingston, Jamaica.

Godley, B.J., Broderick, A.C., Campbell, L.M., Ranger, S. & Richardson, P. (2004). *An assessment of the status and exploitation of marine turtles in the United Kingdom Overseas Territories in the Wider Caribbean*. Final project report for the Department of Environment, Food and Rural Affairs and the Foreign and Commonwealth Office, London.

Groombridge, B. & Luxmoore, R. (1989) *The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade*. CITES Secretariat of the Convention on International Trade in Endangered Species of Wild Flora and Fauna, Cambridge.

Hamann, M., Limpus, C.J., Hughes, G., Mortimer, J.A. & Pilcher, N.J. (2006) *Assessment of the conservation status of the Leatherback turtle in the Indian Ocean and South East Asia, including consideration of the impacts of the December 2004 tsunami on turtles and turtle habitats*. IOSEA Marine Turtle MoU Secretariat, Bangkok.

Hamann, M., Godfrey, M.H., Seminoff, J.A., Arthur, K., Barata, P.C.R., Bjorndal, K.A., Bolten, A.B., Broderick, A.C., Campbell, L.M., Carreras, C., Casale, P., Chaloupka, M., Chan, S.K.F., Coyne, M.S., Crowder, L.B., Diez, C.E., Dutton, P.H., Epperly, S.P., FitzSimmons, N.N., Formia, A., Girondot, M., Hays, G.C., Jiunn, C.I., Kaska, Y., Lewison, R., Mortimer, J.A., Nichols, W.J., Reina, R.D., Shanker, K., Spotila, J.R., Tomás, J., Wallace, B.P., Work, T.M., Zbinden, J. & Godley, B.J. (2010) Global research priorities for sea turtles: informing management and conservation in the 21st century. *Endangered Species Research*, **11**, 245–269.

Harris, E.H. & George, S. (2008) *Nesting Ecology and Conservation of Marine Turtles in the Commonwealth of Dominica, West Indies: 2008 Annual Project Report* (ed. by K.L. Eckert). Prepared by the Dominica Sea Turtle Conservation Organization (DomSeTCO), in partnership with WIDECAST, for the Ministry of Agriculture, Fisheries and Forestry (Forestry, Wildlife and Parks Division). Roseau, Dominica, West Indies.

Havea, S. & MacKay, K.T. (2009) Marine turtle hunting in the Ha'apai Group, Tonga. *Marine Turtle Newsletter*, **123**, 15-17.

Hickey, F. (2003) Traditional marine resource management in Vanuatu: world views in transformation; sacred & profane. *Putting Fishers' Knowledge to Work, Fisheries Centre Research Reports 2002 Volume 11 Number 1* (ed. by N. Haggan, C. Brignall and L. Wood), pp. 117-137. Fisheries Centre, University of British Columbia, Canada.

Hickey, F., R & Johannes, R. (2002) Recent evolution of village based marine resource management in Vanuatu. *SPC Traditional Marine Resource Management and Knowledge Information Bulletin*, **13**, 8-21.

Holland, M. (2013) *Horror video shows sea turtles and dugongs being killed in barbaric fashion by Torres Strait Islanders.* July 1, 2013. The Daily Telegraph (Australia). Available from: http://www.dailytelegraph.com.au/news/nsw/torres-strait-islanders-hunting-animals-under-native-titles-act-slammed-by-animal-welfare-groups/story-fni0cx12-1226672204034 (accessed July 2013).

Hoyle, M. (1994) Continuing sea turtle exploitation in Antigua and Barbuda, West Indies. *Marine Turtle Newsletter*, **64**, 21-22.

Humber, F., Godley, B.J., Ramahery, V. & Broderick, A.C. (2011) Using community members to assess artisanal fisheries: the marine turtle fishery in Madagascar. *Animal Conservation*, **14**, 175–185.

IUCN (2013) *IUCN Red List of threatened species, version 2013.1.* Available at: http://www.iucnredlist.org (accessed March 2013).

Jackson, J.B.C. (1997) Reefs since Columbus. *Coral Reefs*, **16** (Suppl), S23-S32.

Kare, B.D. (1995) A review on the research and fisheries of barramundi, reef fish, dugongs, turtles and Spanish mackerel in the Papua New Guinea side of the Torres Strait. *Joint FFA/SPC workshop on the management of South Pacific inshore fisheries*. South Pacific Commission, Noumea, New Caledonia.

Kennett, R. & Kitchens, J. (2009) *Dugong and Marine Turtle Project. Project Final Report to National Heritage Trust Regional Competitive Component*. North Australian Indigenous Land & Sea Management Alliance, Darwin.

Kennett, R., Munungurritj, N. & Yunupingu, D. (1998) The Dhimurru Miyapunu Project. *Marine turtle conservation and management in northern Australia, Proceedings of a workshop held at the Northern Territory University, Darwin, 3–4 June 1997* (ed. by R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill), pp. 69-75. Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.

Kinch, J. (2002) *The development of a monitoring program for the management and sustainable use of sea turtle resources in the Milne Bay Province, Papua New Guinea*. A proposal prepared for the South Pacific Regional Environment Program, Apia, Western Samoa.

Koch, V., Nichols, W.J., Peckham, H. & Toba, V.d.l. (2006) Estimates of sea turtle mortality from poaching and bycatch in Bahía Magdalena, Baja California Sur, Mexico. *Biological Conservation*, **128**, 327 – 334.

Kwan, D. (1991) The artisanal sea turtle fishery in Daru, Papua New Guinea. Sustainable development for traditional inhabitants of the Torres Strait region: Proceedings of the Torres Strait Baseline Study Conference, Kewarra Beach, Cairns, Queensland. Workshop Series No. 16, D (ed. by D. Lawrence and T.

Cansfield-Smith), pp. 239–240. Great Barrier Reef Marine Park Authority, Townsville.

Lagueux, C.J., Campbell, C. & McCoy, M.A. (2003) Nesting and conservation of the hawksbill turtle, *Eretmochelys imbricata*, in the Pearly Cays, Nicaragua. *Chelonian Conservation and Biology*, **4**, 588–602.

Lam, T., Ling, X., Takahashi, S. & Burgess, E.A. (2011) *Market forces: An examination of marine turtle trade in China and Japan*. TRAFFIC East Asia, Hong Kong.

Lewis, C.B. (1940) The Cayman Islands and marine turtles. *Herpetology of the Cayman Islands. Bulletin of the Institute of Jamaican Sciences Series, no. 2* (ed. by C. Grant), pp. 56-65. Institute of Jamaica, Kingston.

Limpus, C.J. (1980) The green turtle, *Chelonia mydas* (L), in eastern Australia. *Management of turtle resources. Research Monograph 2* pp. 5-22. James Cook University of North Queensland, Townsville.

Limpus, C.J. (2008) *A biological review of Australian marine turtles. 2. Green Turtle* Chelonia mydas *(Linnaeus).* Queensland Government Environmental Protection Agency.

Limpus, C.J., Boyle, M. & Sunderland, T. (2006) New Caledonian loggerhead turtle population assessment: 2005 Pilot Study. *Proceedings of the Second Western Pacific Sea Turtle Cooperative Research and Management Workshop.*

Volume II: North Pacific Loggerhead Sea Turtle (ed. By I. Kinan), Western Pacific Regional Fishery Management Council, pp.77-92. Honolulu.

Maison, K.A., Kinan-Kelly, I. & Frutchey, K.P. (2010) *Green turtle nesting sites and sea turtle legislation throughout Oceania*. U.S. Dep. Commerce, NOAA Technical Memorandum. NMFS-F/SPO-110.

Mancini, A., Senko, J., Borquez-Reyes, R., Póo, J.G., Seminoff, J.A. & Koch, V. (2011) To poach or not to poach an endangered species: elucidating the economic and social drivers behind illegal sea turtle hunting in Baja California Sur, Mexico. *Human Ecology*, **39**, 743-756.

Marco, A., López, O., Abella, E., Varo, N., Martins, S., Gaona, P., Sanz, P. & López-Jurado, L.F. (2010) Massive capture of nesting females is severely threatening the Caboverdian loggerhead population. *Proceedings of the Twenty-eighth Annual Symposium on Sea Turtle Biology and Conservation* (ed by K. Dean and M.C. Lopez-Castro). NOAA Technical Memorandum NMFS-SEFSC-602, pp. 93-94. Miami.

Martin, C.S., Jeffers, J. & Godley, B.J. (2005) The status of marine turtles in Montserrat (Eastern Caribbean). *Animal Biodiversity and Conservation*, **28.2**, 159–168.

McClenachan, L., Jackson, J.B.C. & Newman, M.J.H. (2006) Conservation implications of historic sea turtle nesting beach loss. *Frontiers in Ecology and the Environment*, **4**, 290–296.

Milliken, T. & Tokunaga, H. (1987) *The Japanese sea turtle trade, 1970-1986. A Special Report prepared by TRAFFIC (Japan)*. The Center for Environmental Education, (Washington DC).

Moore, M.K., Bemiss, J.A., Rice, S.M., Quattro, J.M. & Woodley, C.M. (2003) Use of restriction fragment length polymorphisms to identify sea turtle eggs and cooked meats to species. *Conservation Genetics*, **4**, 95–103.

Mrosovsky, N. (1996) Sea turtles. Past and present utilisation. *Wildlife resources. A global account of economic use* (ed. by H.H. Roth and G. Mertz), pp. 88-96. Springer, Toronto.

Mrosovsky, N. (2003) *Predicting extinction: fundamental flaws in IUCN's Red List system, exemplified by the case of sea turtles*. Available at: http://members.seaturtle.org/mrosovsky/.

Nada, M. & Casale, P. (2008) *Marine turtles in the Mediterranean Egypt: threats and conservation priorities.* WWF Italy, Rome.

National Marine Fisheries Service & U.S. Fish and Wildlife Service (1998) *Recovery plan for U.S. Pacific populations of the East Pacific green turtle* (Chelonia mydas). National Marine Fisheries Service, Silver Spring, MD.

Nichols, W.J. (2003) *Biology and conservation of sea turtles in Baja California, Mexico*. Doctor of Philosophy with a major in wildlife ecology University of Arizona, Tucson.

Peckham, S.H., Maldonado-Diaz, D., Koch, V., Mancini, A., Gaos, A., Tinker, M.T. & Nichols, W.J. (2008) High mortality of loggerhead turtles due to bycatch, human consumption and strandings at Baja California Sur, Mexico, 2003 to 2007. *Endangered Species Research*, **5**, 171–183.

Peñate, J.G., Karamoko, M., Bamba, S. & Djadji, G. (2007) An update on marine turtles in Côte d'Ivoire, West Africa. *Marine Turtle Newsletter*, **116**, 7-8.

Petro, G., Hickey, F., R & Mackay, K. (2007) Leatherback turtles in Vanuatu. *Chelonian Conservation and Biology*, **6**, 135-137.

Pritchard, P.C.H. (2003) Global Status of Sea Turtles: An Overview. *Inter-American Convention for the Protection and Conservation of Sea Turtles First Meeting of the Parties, Final Report* (ed. by IAC Secretariat), pp. 81-93. Secretariat Pro Tempore, Inter-American Convention for the Protection and Conservation of Sea Turtles, San José, Costa Rica.

Reuter, A. & Allan, C. (2006) *Tourists, Turtles and Trinkets: a look at the trade in marine turtle products in the Dominican Republic and Colombia*. TRAFFIC North America, Washington D.C.

Richardson, P., Broderick, A., Campbell, L., Godley, B. & Ranger, S. (2006) Marine turtle fisheries in the UK Overseas Territories of the Caribbean: Domestic legislation and the requirements of multilateral agreements. *Journal of International Wildlife Law and Policy*, **9**, 223–246.

Rudrud, R.W. (2010) Forbidden sea turtles: Traditional laws pertaining to sea turtle consumption in Polynesia (including the Polynesian Outliers). *Conservation and Society*, **8**, 84-97.

Rudrud, R.W., Kroeker, J.W., Leslie, H.Y. & Finney, S.S. (2007) The sea turtle wars: Culture, war and sea turtles in The Republic of the Marshall Islands. *SPC Traditional Marine Resource Management and Knowledge Information* **21**, 3-29.

Stoddart, D.R. (1980) Little Cayman: ecology and significance. *Atoll Research Bulletin*, **241**, 171-180.

Vander Velde, N. (2008) *A sea turtle genetic sampling, data collection and analysis project in the Marshall Islands*. Women United Together in the Marshall Islands (WUTMI), Majuro.

Wallace, B.P., Lewison, R., McDonald, S.L., McDonald, R.K., Kot, C.Y., Kelez, S., Bjorkland, R.K., Finkbeiner, E.M., Helmbrecht, S. & Crowder, L.B. (2010) Global patterns of marine turtle bycatch. *Conservation Letters*, **3**, 1–12.

Wayne King, F. (1995) Historical review of the decline of the green turtle and the hawksbill. *Biology and Conservation of Sea Turtles. Revised Edition* (ed. by K.A. Bjorndal), pp. 183-188. Smithsonian Institution Press, Washington D.C.

WWF (2005) *Recent news from the WWF Africa & Madagascar marine turtle programme.* WWF, Gland.

Figure 1. The number of countries or territories that permit the direct take of turtles (as of 1st January 2013) showing type of legislation in place or absence. N = Protection absent; L = Legislation allows for a level of harvest of one or more species of turtles; T = Full protection but traditional hunting exemptions exist; M = Moratorium in place only at present; U = Unable to verify legislation.

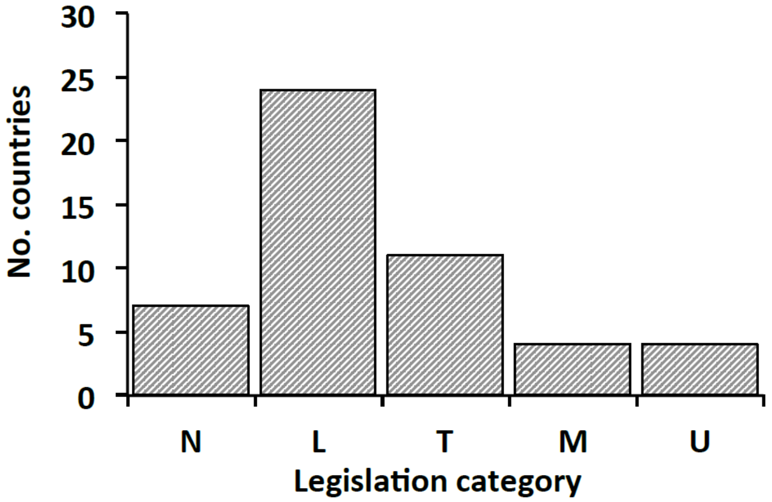


Figure 2. The current estimate of annual legal take by species (*n* = 42 countries) (data from 1 January 2010 to 1 January 2013). O. Ridley = Olive Ridley; K. Ridley = Kemp's Ridley.

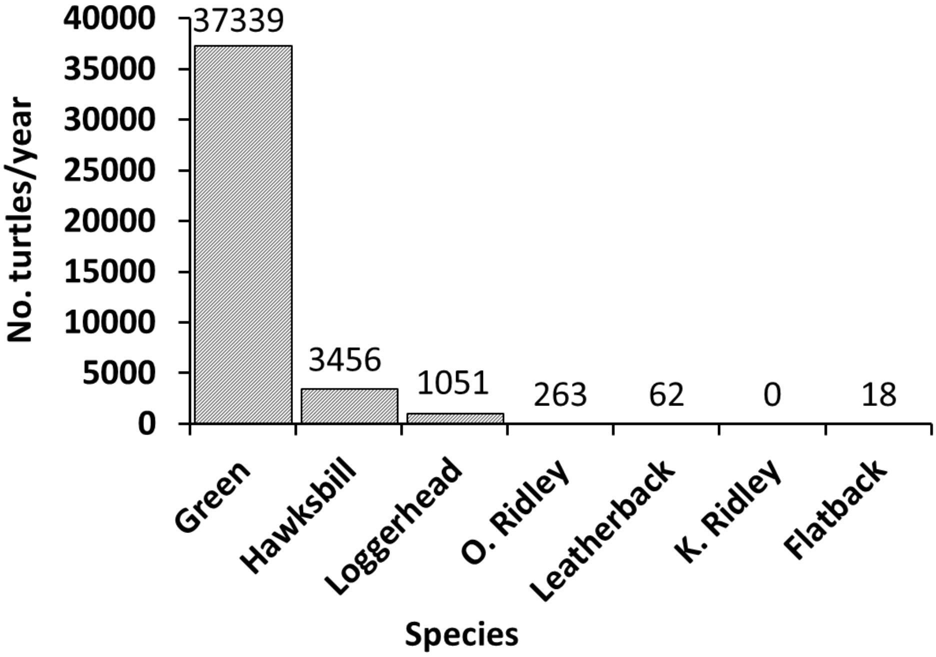


Figure 3. Estimated current annual legal marine turtle take by country or territory (data from 1 January 2010 to 1 January 2013). Data for the Caribbean (CAR) and Pacific (PAC) regions have been grouped and are shown in further detail in Fig. 4a,b. No take = no known legal or illegal take; Unquantified take = illegal take data found only or take known to occur but no data available. *Country with moratorium. Country abbreviations (countries in brackets indicate dependency): ALB = Albania; AND = Andaman and Nicobar Islands (India); AUS = Australia; BOS = Bosnia and Herzegovina; CHI = Chile; COP = Colombia (Pacific coast); GUY = Guyana; IND = Indonesia; JAP = Japan; KIR = Kiribati; MAL = Maldives; MAR = Marshall Islands: MIC = Federated States of Micronesia; MXA = Mexico (Atlantic coast); MXP = Mexico (Pacific coast); PAL = Palau; PAP = Papua New Guinea; PIT = Pitcairn Islands (UK); SAO = Sao Tome and Principe; SYR = Syria. Take is also shown for countries with unverified legislation (ALG = Algeria; NKO = North Korea; SOM = Somalia). Note: Position of symbols is not representative of locations of take data.

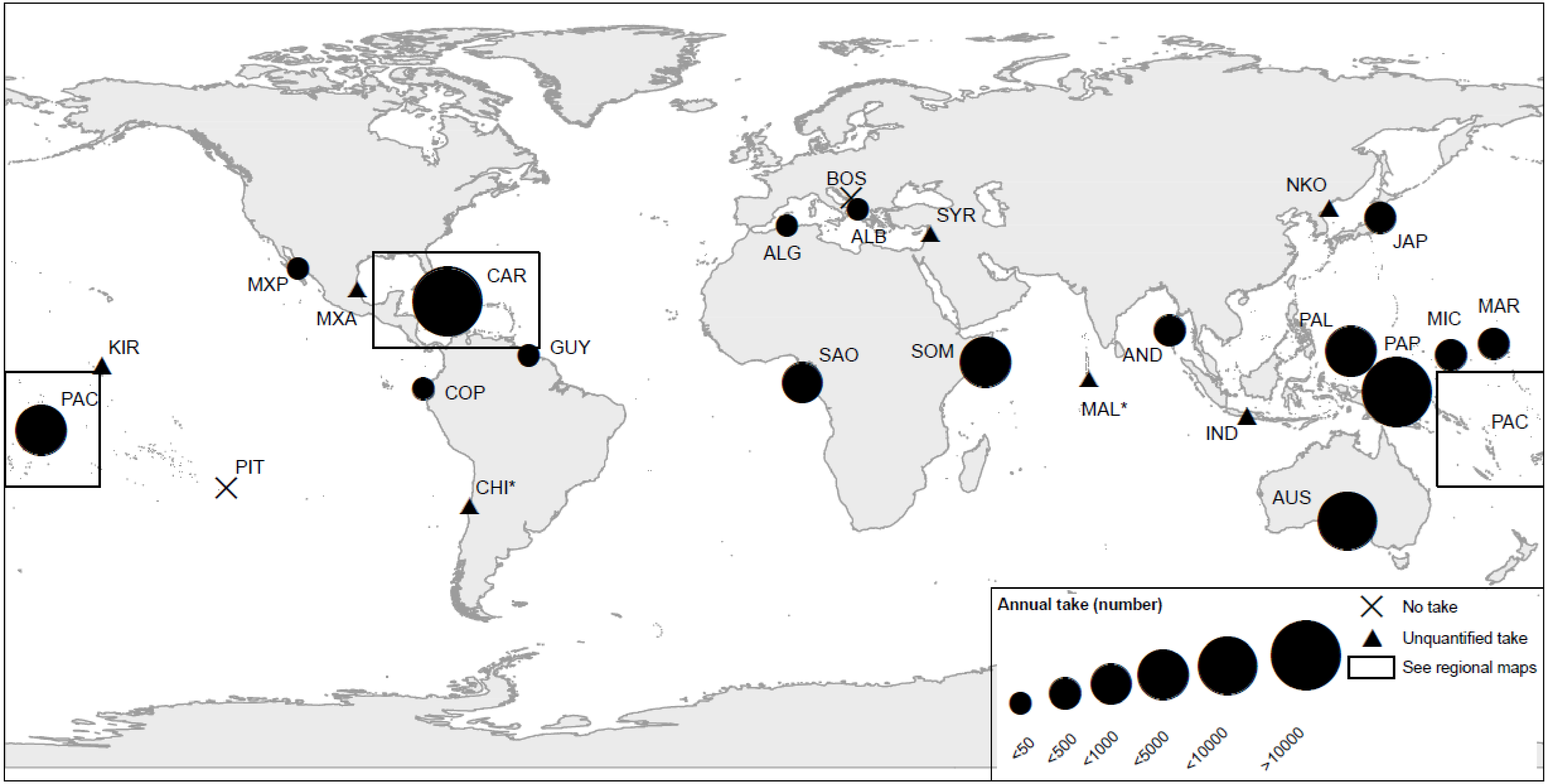
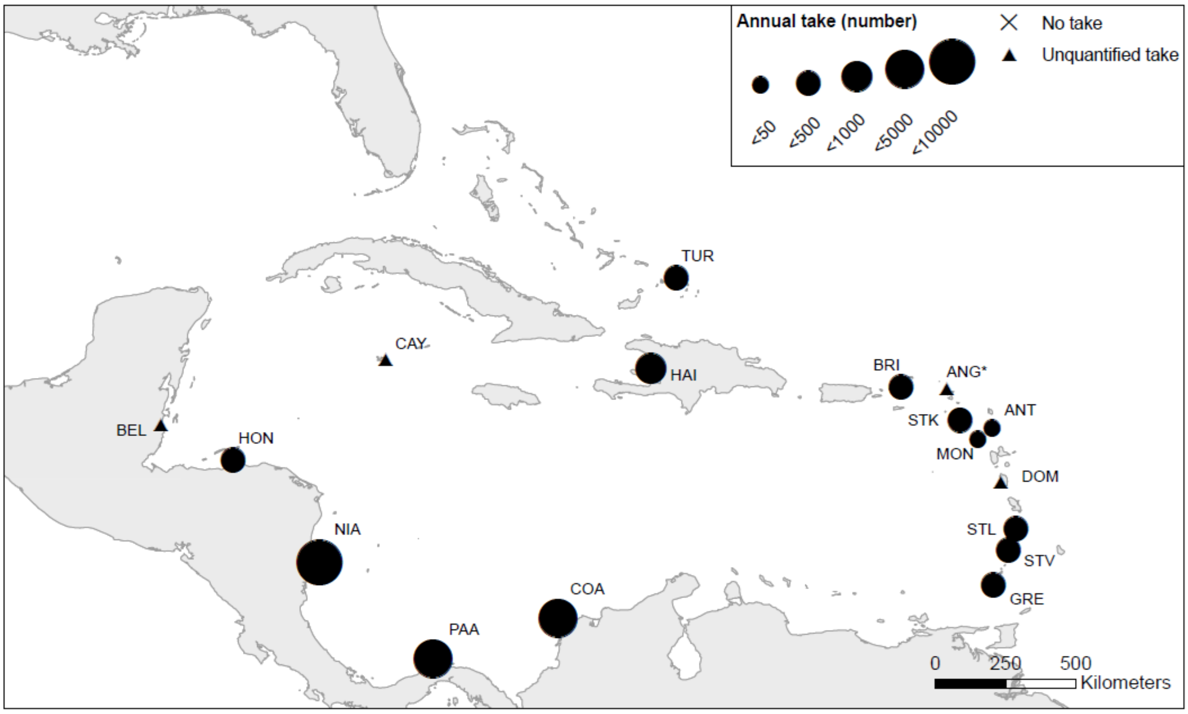

BOS
NKO
SYR
JAP
ALB
ALG
MXP
CAR
MXA
PAL
MIC
MAR
KIR
GUY
SAO
SOM
AND
PAP
PAC
COP
MAL*
IND
PAC
PIT
CHI*
AUS
Annual take (number)
No take
Unquantified take
See regional maps
<50
<500
<1000
<5000
<10000
>10000

Figure 4. Estimated annual current legal marine turtle take for (a) the Caribbean and (b) the Pacific regions highlighted in Fig. 3 (data from 1 January 2010 to 1 January 2013). No take = no known legal or illegal take; Unquantified take = illegal take data found only or take known to occur but no data available. *Country with moratorium. Country abbreviations (countries in brackets indicate dependency): (a) ANG = Anguilla (UK); ANT = Antigua and Barbuda; BEL = Belize; BRI = British Virgin Islands (UK); CAY = Cayman Islands (UK); COA = Colombia (Atlantic coast); DOM = Dominica; GRE = Grenada; HAI = Haiti; HON = Honduras; MON = Montserrat (UK); NIA = Nicaragua (Atlantic coast); STK = St. Kitts and Nevis; STL = St. Lucia; STV = St. Vincent and the Grenadines; TUR = Turks and Caicos. Take is also shown for countries with unverified legislation: PAA = Panama (Atlantic coast). This take was not included in grouped take CAR in Fig. 3. Country abbreviations (countries in brackets indicate dependency): (b) COO = Cook Islands (New Zealand); FIJ = Fiji; NAU = Nauru; NEW = New Caledonia (France); NIU = Niue; SAM = Samoa; SOL = Solomon Islands; TOK = Tokelau (New Zealand); TON = Tonga; TUV = Tuvalu; VAN = Vanuatu; WAL = Wallis and Futuna (France). Note: Position of symbols is not representative of locations of take data.


Annual take (number)
<50
<500
<1000
<5000
<10000
No take
Unquantified take
TUR
CAY
HAI
BRI
ANG*
ANT
STK
MON
DOM
BEL
HON
NIA
STL
STV
GRE
COA
PAA
0
250
500
Kilometers

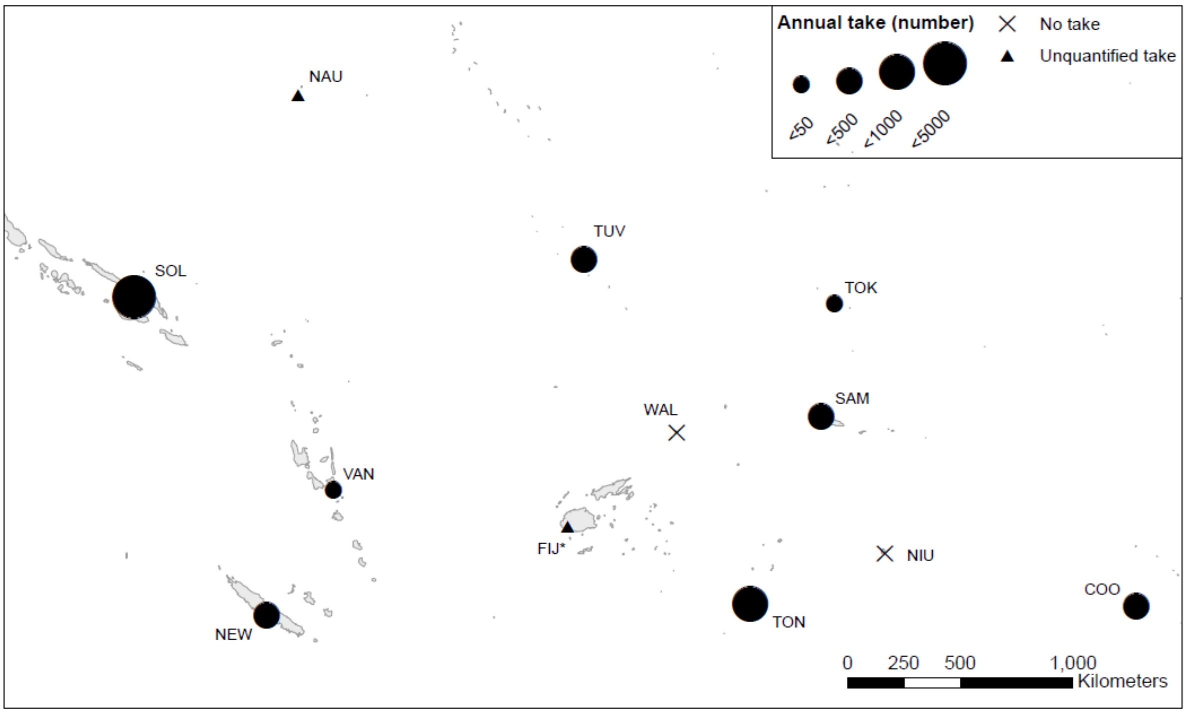

Annual take (number)
<50
<500
<1000
<5000
No take
Unquantified take
NAU
TUV
SOL
TOK
SAM
WAL
VAN
FIJ*
NIU
COO
TON
NEW
0
250
500
1,000
Kilometers

Figure 5. The 10 countries with the highest annual legal take of marine turtles as of 1st January 2013. Country abbreviations are: PAP = Papua New Guinea, NIA = Nicaragua (Atlantic coast), AUS = Australia, COA = Colombia (Atlantic coast), SOL = Solomon Islands, PAL = Palau, HAI = Haiti, TON = Tonga, SAO = Sao Tome and Principe; STV = St. Vincent and the Grenadines. *Legislation prohibits take in Principe only since 2009.

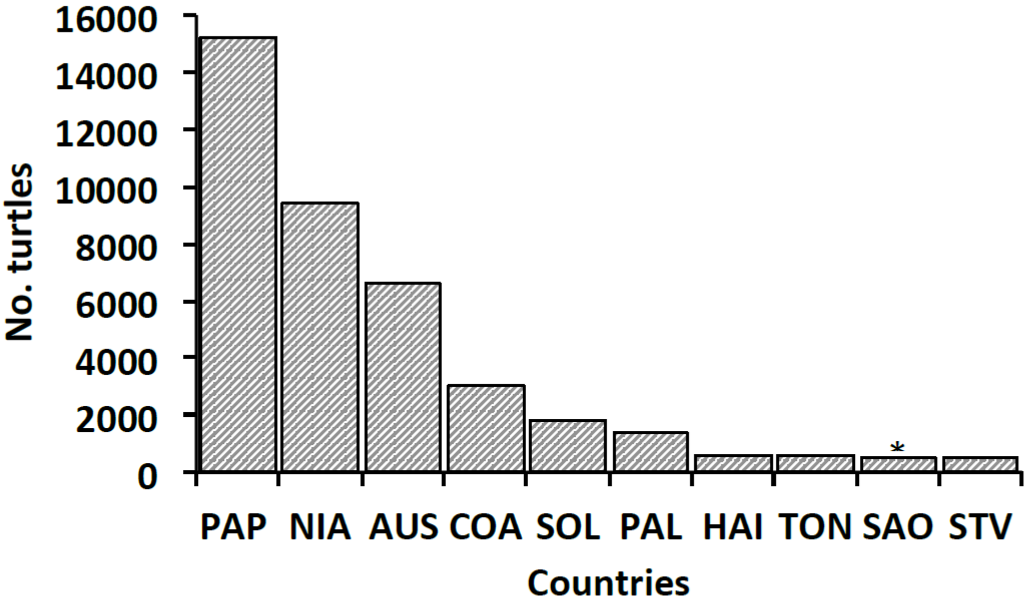


Figure 6. The estimated annual legal take of turtles per decade since 1980 for those countries and territories (*n* = 46) within this study, including those with current moratoria. Current represents data from 1 January 2010 to 1 January 2013 and does not include countries with current moratoria (*n* = 42).

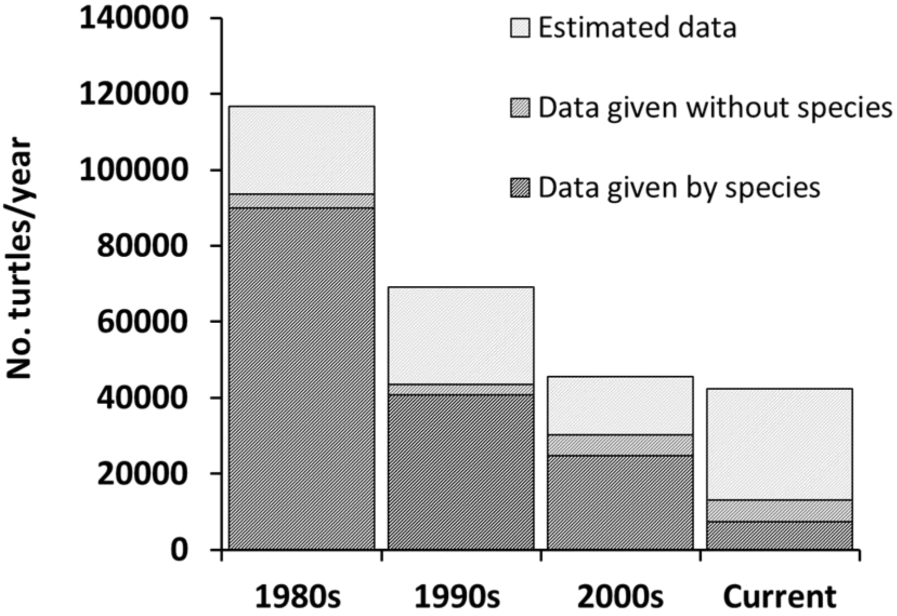


Figure S1. Past estimated annual turtle take for (a) green, (b) hawksbill, (c) olive ridley, (d) loggerhead and (e) leatherback for those countries and territories (*n* = 46) within this study, including those with current moratoria). Current represents data from 1st January 2010 to 1st January 2013 and does not include countries with current moratoria (*n* = 42). Numbers above bars on graph (c) indicate actual data value.

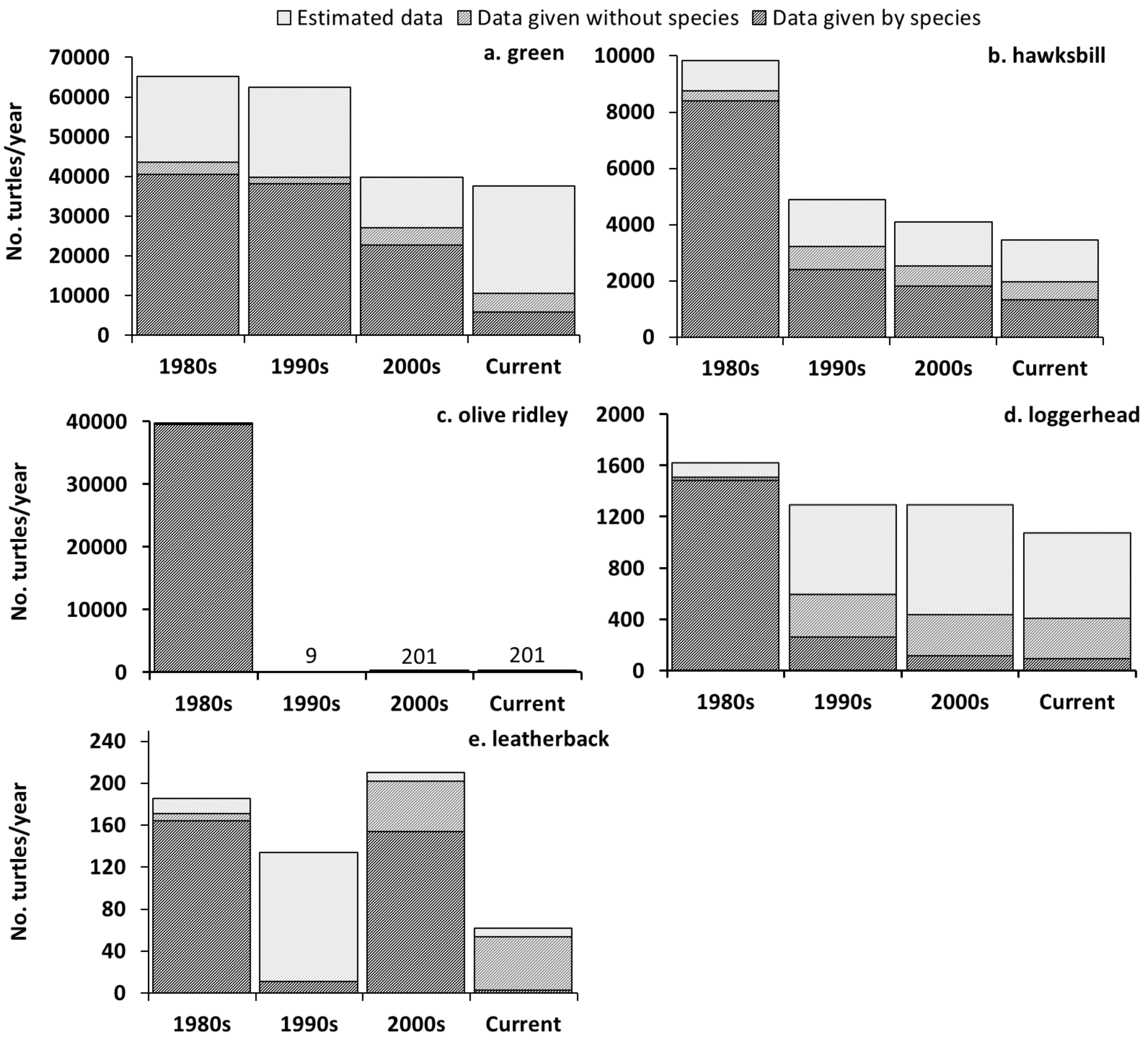


Figure. S2. Estimated global breakdown by species of legal marine turtle take by country or territory (data from 1st January 2010 to 1st January 2013). Data for the Caribbean (CAR) and Pacific (PAC) regions has been grouped and is shown in further detail in Figures S3(a) and S3(b). No take = no known legal or illegal take; Unquantified take = illegal take data found only or take known to occur but no data available. Cm = green; Ei = hawksbill; Cc = loggerhead; Lo = olive ridley; Dc = leatherback. * = Country with moratorium.

Country abbreviations (countries in brackets indicate dependency): ALB = Albania; AND = Andaman and Nicobar Islands (India); AUS = Australia; BOS = Bosnia and Herzegovina; CHI = Chile; COP = Colombia (Pacific coast); GUY = Guyana; IND = Indonesia; JAP = Japan; KIR = Kiribati; MAL = Maldives; MAR = Marshall Islands: MIC = Federated States of Micronesia; MXA = Mexico (Atlantic coast); MXP = Mexico (Pacific coast); PAL = Palau; PAP = Papua New Guinea; PIT = Pitcairn Islands (UK); SAO = Sao Tome and Principe; SYR = Syria.

Species breakdown is also shown for countries with unverified legislation (ALG = Algeria; NKO = North Korea; SOM = Somalia).

Note: Position of symbols is not representative of locations of take data.

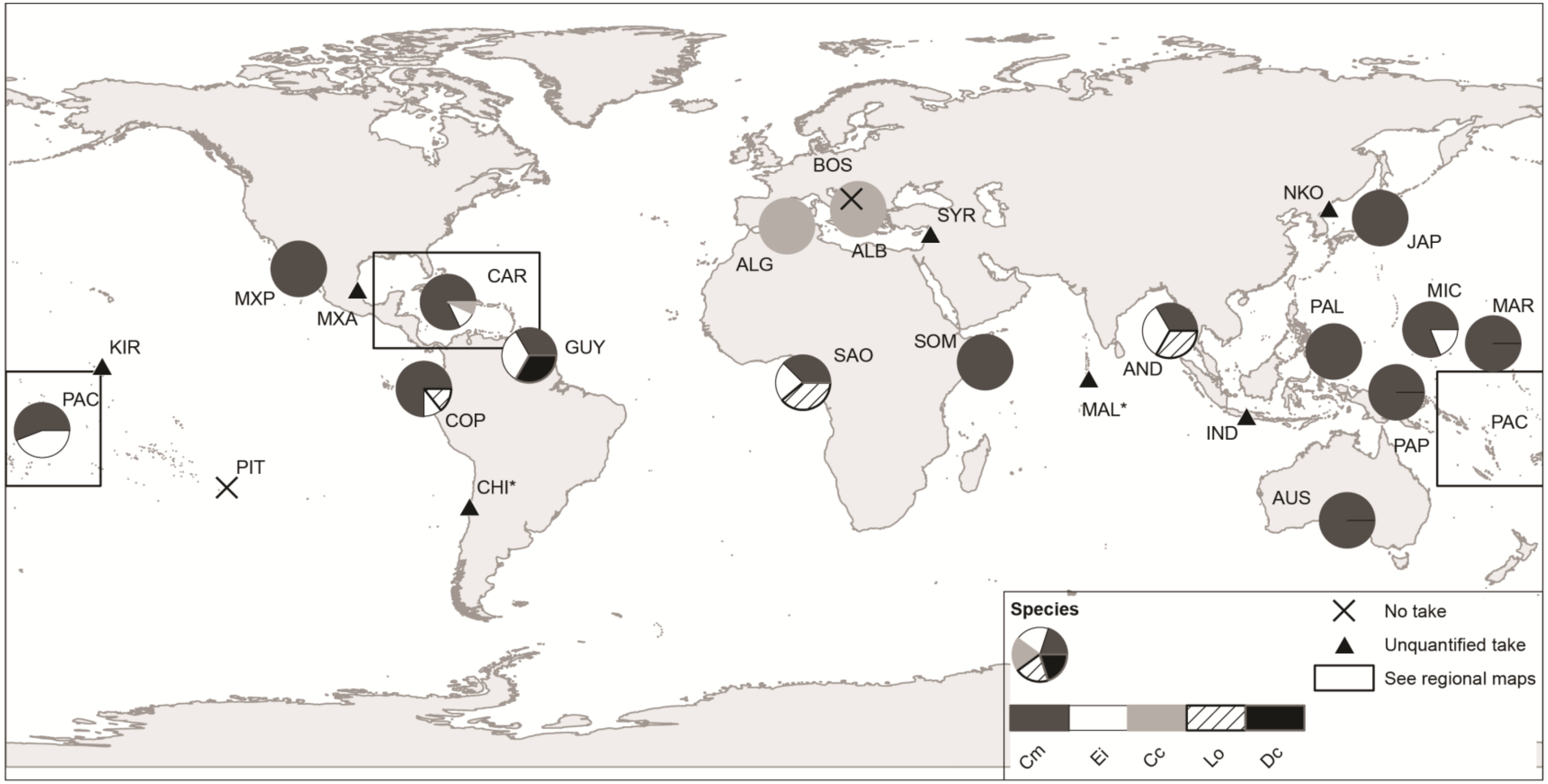

BOS
NKO
JAP
SYR
ALG
ALB
MXP
CAR
MXA
MIC
MAR
PAL
GUY
KIR
SAO
SOM
AND
PAC
COP
MAL*
IND
PAC
PAP
PIT
CHI*
AUS
Species
No take
Unquantified take
See regional maps
Cm
Ei
Cc
Lo
Dc

Figure S3. Estimated global breakdown by species of legal marine turtle take by country or territory for (a) the Caribbean and (b) the Pacific regions highlighted in Figure S2 (data from 1st January 2010 to 1st January 2013). No take = no known legal or illegal take; Unquantified take = illegal take data found only or take known to occur but no data available. Cm = green; Ei = hawksbill; Cc = loggerhead; Lo = olive ridley; Dc = leatherback. * = Country with moratorium.

Country abbreviations (countries in brackets indicate dependency): Figure S3a: ANG = Anguilla (UK); ANT = Antigua and Barbuda; BEL = Belize; BRI = British Virgin Islands (UK); CAY = Cayman Islands (UK); COA = Colombia (Atlantic coast); DOM = Dominica; GRE = Grenada; HAI = Haiti; HON = Honduras; MON = Montserrat (UK); NIA = Nicaragua (Atlantic coast); STK = St. Kitts and Nevis; STL = St. Lucia; STV = St. Vincent and the Grenadines; TUR = Turks and Caicos (UK).

Species breakdown is also shown for countries with unverified legislation: PAA = Panama (Atlantic coast). These data were not included in grouped data for CAR in Figure S2.

Country abbreviations (countries in brackets indicate dependency): Figure S3b: COO = Cook Islands (New Zealand); FIJ = Fiji; NAU = Nauru; NEW = New Caledonia (France); NIU = Niue; SAM = Samoa; SOL = Solomon Islands; TOK = Tokelau (New Zealand); TON = Tonga; TUV = Tuvalu; VAN = Vanuatu; WAL = Wallis and Futuna (France).

Note: Position of symbols is not representative of locations of take data.

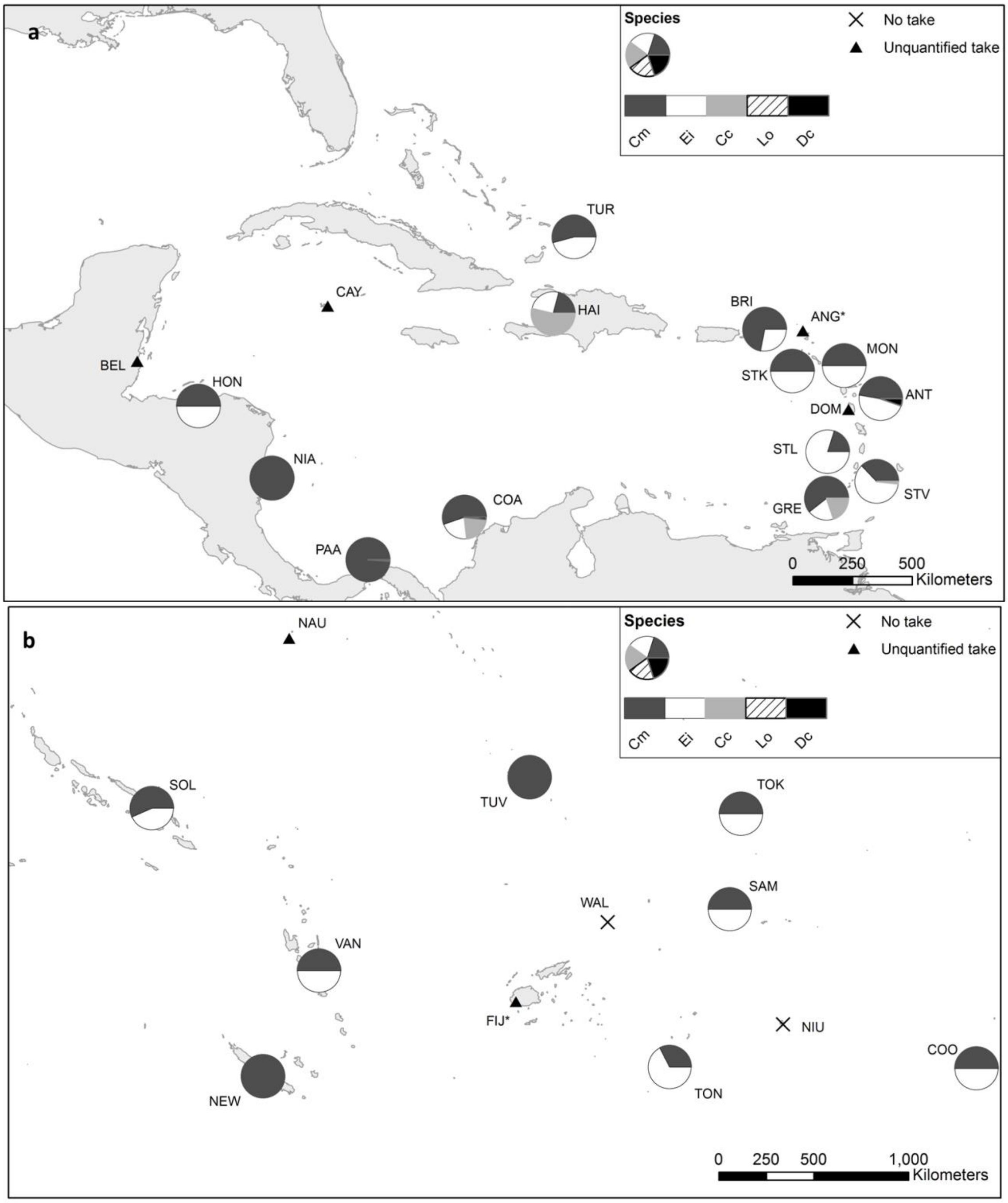

a
Species
Cm
Ei
Cc
Lo
Dc
No take
Unquantified take
TUR
CAY
HAI
BRI
ANG*
BEL
HON
MON
STK
ANT
DOM
NIA
STL
STV
COA
GRE
PAA
0
250
500
Kilometers
b
NAU
SOL
TUV
TOK
SAM
WAL
VAN
FIJ*
NIU
COO
NEW
TON
0
250
500
1,000
Kilometers

Figure S4. Top countries or territories by species for current estimated annual legal take of (a) green, (b) hawksbill, (c) olive ridley, (d) loggerhead and (e) leatherback for countries within this study (n = 42) (data from 1st January 2010 to 1st January 2013). Country abbreviations are (countries in brackets indicate dependency): ALB = Albania; AND = Andaman and Nicobar Islands (India); ANT = Antigua and Barbuda; AUS = Australia; COA = Colombia (Atlantic coast); COP = Colombia (Pacific coast); GRE = Grenada; GUY = Guyana; HAI = Haiti; HON = Honduras; MAR = Marshall Islands; NIA = Nicaragua (Atlantic coast); PAL = Palau; PAP = Papua New Guinea; SOL = Solomon Islands; SAO = Sao Tome and Principe; TON = Tonga; STL = St. Lucia; STV = St. Vincent and the Grenadines; TON = Tonga; TUR = Turks and Caicos (UK); VAN = Vanuatu. Numbers above bars on graphs (a) (c) and (d) indicate actual data value. *Legislation prohibits take in Principe only since 2009.

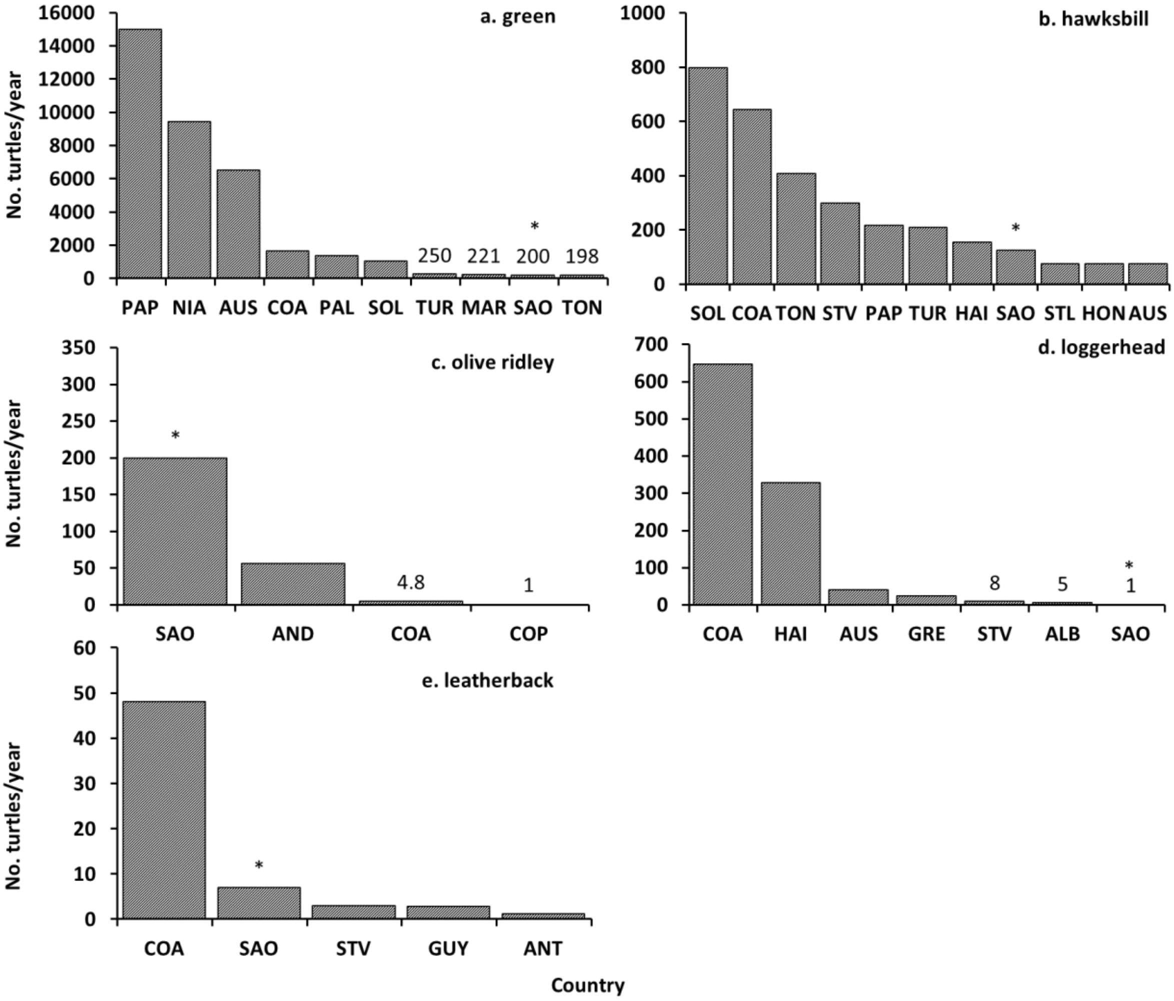

a. green
No. turtles/year
16000
14000
12000
10000
8000
6000
4000
2000
0
250
221
*
200
198
PAP
NIA
AUS
COA
PAL
SOL
TUR
MAR
SAO
TON
b. hawksbill
1000
800
600
400
200
0
*
SOL
COA
TON
STV
PAP
TUR
HAI
SAO
STL
HON
AUS
c. olive ridley
No. turtles/year
350
300
250
200
150
100
50
0
*
4.8
1
SAO
AND
COA
COP
d. loggerhead
700
600
500
400
300
200
100
0
8
5
*
1
COA
HAI
AUS
GRE
STV
ALB
SAO
e. leatherback
No. turtles/year
60
50
40
30
20
10
0
*
COA
SAO
STV
GUY
ANT
Country

Table S1. Estimated current annual legal take by species for countries with legal marine turtle fisheries as of 1st January 2013. ND = No data found. A = Species absent. R = Species rare. P = Species fully protected. NA = Not applicable. 0 = No legal take known.

Country abbreviations (countries in brackets indicate dependency): ALB = Albania; ALG = Algeria; AND = Andaman and Nicobar Islands (India); ANG = Anguilla (UK); ANT = Antigua and Barbuda; AUS = Australia; BEL = Belize; BOS = Bosnia and Herzegovina; BRI = British Virgin Islands (UK); CAY = Cayman Islands (UK); CHI = Chile; COA = Colombia (Atlantic coast); COO = Cook Islands (New Zealand); COP = Colombia (Pacific coast); DOM = Dominica; FIJ = Fiji; GRE = Grenada; GUY = Guyana; HAI = Haiti; HON = Honduras; IND = Indonesia; JAP = Japan; KIR = Kiribati; MAL = Maldives; MAR = Marshall Islands: MIC = Federated States of Micronesia; MON = Montserrat (UK); MXA = Mexico (Atlantic coast); MXP = Mexico (Pacific coast); NAU = Nauru; NEW = New Caledonia (France); NKO = North Korea; NIA = Nicaragua (Atlantic coast); NIU = Niue; PAA = Panama (Atlantic coast); PAL = Palau; PAP = Papua New Guinea; PIT = Pitcairn Islands (UK); SAM = Samoa; SAO = Sao Tome and Principe; SOL = Solomon Islands; SOM = Somalia; STK = St. Kitts and Nevis; STL = St. Lucia; STV = St. Vincent and the Grenadines; SYR = Syria; TOK = Tokelau (New Zealand); TON = Tonga; TUR = Turks and Caicos (UK); TUV = Tuvalu; VAN = Vanuatu; WAL = Wallis and Futuna (France).

[1] Andaman and Nicobar Islands are a Union Territory of India.

[2] Anguilla, British Virgin Islands, Cayman Islands, Montserrat, Turks and Caicos and Pitcairn Islands are all overseas territories of the UK.

[3] The Cook Islands are self-governing in free association with New Zealand.

[4] New Caledonia is a territorial collectivity (or a *sui generis* collectivity) of France since 1998.

[5] Tokelau is a self-administering territory of New Zealand.

[6] Wallis and Futuna is an overseas territory of France.

[+] No national estimate available, local estimate only.

Numbers in parentheses indicate that some was data originally unidentified by species.

[a] Best guess, not an official estimate.

[b] Includes current or historical direct take estimates (not presented here) calculated using volumes of bekko or meat.

[c] Includes unidentified data broken down into species before calculations (either current and/or historical data).

[d] Only data on poached nesting females.

[e] To be noted: Department has limited information and all Nevis fishers were not willing to cooperate in providing information.

Leg. Cat. = Legislation category (see Figure 1). Legislation categories:

N = Protection absent [some islands or communities have their own regulations]*protection administered at some level through other regulations

L = Legislation allows for a level of harvest of one or more species of turtles [permit/licence required] [[subsistence only]]{ad hoc agreement in Bali for approximately 300-400 turtles/year from hatcheries to be used in religious rituals despite all species being protected}*banned in Principe ^written cabinet approval.

T = Full protection but traditional hunting exemptions exist [permit/licence required] [[personal/domestic use only]] **licence granted for those who traditionally hunted turtles.

M = Moratorium in place only at present [permit/licence required]

U = Unable to verify legislation. *In Panama the legal situation is considered confused as although all turtles species were protected in 1980 other laws allow subsistence fishing and recognise traditional user rights. **Due to the fact that several autonomous regions now exist in Somalia, there is no national legislation to protect marine turtles. However, in Puntland State turtles are protected by a local decree and are fully protected by law in Somaliland.

Country											
Country Code	**Leg. Cat.**	**Leg. Ref.**	**Green**	**Hawksbill**	**Loggerhead**	**Olive Ridley**	**Leatherback**	**Trend since 2000 (clear = pers. comm.)**	**Estimated illegal take/year**	**Refs.**
ALB[+]	N	1	ND	A	(5.0)	A	ND	◁▷	NA	2, 3, M. White pers. comm.
AND[1]	T	4	(57.0)	(57.0)	A	(57.0)	ND	◁▷	ND	5, M. Chandi pers. comm.
ALG	U	ND	A	A	116.0	A	A	ND	ND	6

Country										
Country Code	Leg. Cat.	Leg. Ref.	Green	Hawksbill	Loggerhead	Olive Ridley	Leatherback	Trend since 2000 (clear = pers. comm.)	Estimated illegal take/year	Refs.
ANG[2]	M	7, 8	P[c]	P[c]	P	A	P	◀▶	<100	9 – 10, J. Gumbs, pers. comm.
ANT	L	11	(10.0)	(10.0)	ND	A	1.0	◀▶	50	12 – 14
AUS	[[T]]	15	6522.5[c]	75.0[c]	40.0	ND	ND	▼	ND	16 – 28
BEL	[T]	29	0[c]	P[c]	0[c]	R	R	▽	10	30-34, L. Searle pers. comm; I. Majil pers. comm.
BOS	N	T. Kupusovic pers. comm.	ND	A	ND	A	A	ND	NA	T. Kupusovic pers. comm.
BRI[2]	L	35	122.5[c]	47.5[c]	P	A	P	▽	ND	9, 36-40, S. Davies pers. comm., S. Gore pers. comm.
CAY[2]	T**	41	0[c]	P[c]	0	A	P	▽	4	9, 42 – 44, J. Blumenthal pers. comm.
CHI	M	45	P	A	P	P	P	◁▷	1	46 – 48, J. Azócar pers. comm.
COA[+]	[[L]]	49, C. Ceballos pers. comm	(1655.4)	(645.8)	(645.8)	(4.8)	(48.1)	◀▶	ND	50-53
COO[+][3]	[N]*	54, E. Munro pers. comm.	(50.0)	(50.0)	ND	A	ND	▽	NA	54 – 55, M. White pers. comm.
COP[+]	[[L]]	49	5.0	1.0	ND	1.0	ND	◀▶	ND	56 – 57
DOM[+]	L	58	ND	ND[c]	ND	A	ND	◀▶	8[d]	14, 42, 59 – 65
FED[+]	L	66	(165.4)	(38.6)	A	ND	ND	◀▶	9	66 – 69, S. Palik pers. comm.
FIJ[+]	[M]	70	ND	ND[b]	ND	A	ND	▽	3261	42, 71 – 76, M. Raicebe pers. comm.
GRE	[L]	77	72.5	23.5	23.5	R	P	▽	ND	78 – 80, C. Isaac pers. comm.
GUY	N*	Environmental Protection Agency, pers. comm.	(2.8)	(2.8)	R	R	(2.8)	▽	NA	81, M. Kalamandeen pers. comm..
HAI	L	82	128.0	155.2[b]	328.0	A	ND	◀▶	ND	42, 83 – 84
HON[+]	T	85, C. Montalván pers. comm.	(75.0)	(75.0)[b]	ND	A	ND	◀▶	ND	42, 86 – 87

Country										
Country Code	**Leg. Cat.**	**Leg. Ref.**	**Green**	**Hawksbill**	**Loggerhead**	**Olive Ridley**	**Leatherback**	**Trend since 2000 (clear = pers. comm.)**	**Estimated illegal take/year**	**Refs.**
IND[+]	{L}	88, I.B. Windia Adnyana pers. comm.	P	P	P	P	P	▼	3279	72, 89 – 98
JAP	[T]	99, Tokyo Metropolitan Government pers. comm.	130.0	P	P	P	P	◀▶	ND	H. Suganuma pers. comm.
KIR	L	100	ND	ND	ND	ND	ND	△	ND	101 – 102, N. Teariki-Ruatu pers. comm.
MAL	M	103	P	P[b]	P	P	P	◀▶	ND	42, 104 – 105
MAR[+]	L	106	221.0	6.0	A	ND	ND	▲	ND	107 – 110
MON[2]	L	111, A. Ponteen pers. comm.	(3.8)[c]	(3.8)[c]	ND	A	ND	▼	ND	9, 112 – 113, A. Ponteen pers. comm.
MXA	[T]	114, 115	ND	P	P	P	P	◀▶	ND	116 – 117
MXP	[T]	114, 115	3.0	P	P	P	P	▽, ◁▷	6644	118 – 129, A. Mancini pers. comm., W.J. Nicholls pers. comm.
NAU	N*	130, M. Depaune pers. comm.	ND	ND	A	A	A	△	NA	130, M. Depaune pers. comm.
NEW[+4]	[T]	131, 132	176.0	P	P	A	P	◀▶	100	133, 164, Direction de l'Environnement Province Sud pers. comm., Direction du Développement Economique et de l'Environnement Province Nord pers. comm.
NKO	U	ND	ND	ND	ND	ND	ND	ND		
NIA	[[L]]	134, 135	9413.0	P	P	A	P	▽	403	42, 136 – 139, C. Lagueux pers. comm.
NIU	L^	140	0	0	A	A	A	NA	ND	J. Tafatu pers. comm.
PAA	U*	13, 141	3000.0	27.0	0	A	34.0	◀▶	ND	42, 141, 142 – 149
PAL	L	150	1362.1	ND	ND	ND	ND	◀▶	ND	151 – 152
PAP	L	153	15000.0	217.4	ND	ND	P	◀▶	3	154 – 163

Country			Green	Hawksbill	Loggerhead	Olive Ridley	Leatherback	Trend since 2000 (clear = pers. comm.)	Estimated illegal take/year	Refs.
Country Code	Leg. Cat.	Leg. Ref.								
PIT[2]	[T]	164	0	0	A	A	A	◀▶	ND	165, M. Christian pers. comm.
SAM[+]	L	166	(46.3)	(46.3)	A	A	ND	▽	ND	167 – 168, J. Ward pers. comm.
SAO	L*	169	200.0	125.0	1.0	200.0	7.0	◀▶	ND	170 – 173, R. Ferreira pers. comm.[a]
SOL[+]	L	174	(1043.0)	(800.0)[b]	ND	ND	P	◀▶	ND	42, 165, 175 – 179, R. Masu pers. comm.
SOM	U**	180, J. Torrens pers. comm.	3500.0	ND[b]	ND	ND	ND	◀▶	ND	42, 181 – 183
STK[+]	L	184	(50.0)	(50.0)	ND	A	ND	◀▶	ND	14, 185 – 188, A. Arthurton pers. comm[e]
STL	L	189	19.2	76.8[b]	R	A	P	◀▶	17.5	14, 42, 190 – 192, S.Williams-Peter pers. comm.
STV	L	193	181.0	299.0[b]	8.0	A	3.0	▽	ND	14, 42, 194 – 195, L. Edwards. pers. comm.
SYR	N	196	ND	A	ND	A	R	ND	NA	196 – 197
TOK[5]	[N]*	F. Tulafono pers. comm., L. Suveinakama pers. comm.	(22.5)	(22.5)	ND	A	A	▽	NA	198, F. Tulafono pers. comm.
TON[+]	L	199	198.0	410.0	A	ND	P	△	ND	200, P. Ngaluafe pers. comm.
TUR[2]	L	201	250.0	210.5	ND	A	ND	◁▷	ND	9, 202 – 204, Stringell pers. comm.
TUV	L	205	(147.0)	ND	A	A	ND	◀▶	ND	206, S. Alefaio pers. comm.
VAN[+]	[T]	66, F. Hickey pers. comm.	(7.5)	(7.5)	ND	ND	0	▼	10	207, F. Hickey pers. comm.
WAL[6]	[T]	Fisheries Act 2005 (B. Mugneret pers. comm.)	0	A	A	A	A	ND	ND	B. Mugneret pers. comm.

Appendix S1. Supporting references.

1. Casale, P. & Margaritoulis, D. (2010) *Sea turtles in the Mediterranean: Distribution, threats and conservation priorities*. IUCN, Gland.
2. Haxhiu, I. (2010) Albania. *Sea turtles in the Mediterranean: Distribution, threats and conservation priorities* (ed. by P. Casale and D. Margaritoulise), pp. 15-28. IUCN, Gland.
3. White, M., Haxhiu, I., Kouroutos, V., Gace, A., Vaso, A., Beqiraj, S., Plytas, A. & Dedej, Z. (2006) *Rapid Assessment Survey of important marine turtle and monk seal habitats in the coastal area of Albania October – November 2005*. GEF/SGP Tech Report. Meddasset, Athens.
4. Andrews, H.V., Tripathy, A., Aghue, S., Glen, S., John, S. & Naveen, K. (2006) The status of sea turtle populations in the Andaman and Nicobar Islands of India. *Towards an Integrated and Collaborative Sea Turtle Conservation Programme in India: a UNEP/CMS-IOSEA Project Report* (ed. by K. Shanker and H.V. Andrews), pp. 71-82. Centre for Herpetology/Madras Crocodile Bank Trust, Tamil Nadu.
5. Andrews, H.V., Krishnan, S. & Biswas, P. (2006) Distribution and status of marine turtles in the Andaman and Nicobar Islands. *Marine Turtles of the Indian Subcontinent* (ed. by K. Shanker and B.C. Choudhury), pp. 33-57. India: Universities Press, Hyderabad.
6. Laurent, L. (1990) Les tortues marine en Algérie et au Maroc (Méditerranée). *Bulletin de la Société Herpétologique de France*, **55**, 1-23.
7. Fisheries Protection Act, 2000; Fisheries Protection Regulation 2000. Available from: http://www.seaturtle.org/mtrg/projects/tcot/finalreport/appd3.1.2.pdf (accessed July 2013).
8. Wynne, S. (2009) *Progress report on sea turtle research conducted by The Department of Fisheries and Marine Resources during 2007 and 2008 in Anguilla.* Department of Fisheries and Marine Resources for the Government of Anguilla.
9. Godley, B.J., Broderick, A.C., Campbell, L.M., Ranger, S. & Richardson, P. (2004). *An assessment of the status and exploitation of marine turtles in the United Kingdom Overseas Territories in the Wider Caribbean*. Final project report for the Department of Environment, Food and Rural Affairs and the Foreign and Commonwealth Office.
10. Hall, K. (1987) *National Report to WATS II for Anguilla*. Prepared for the Second Western Atlantic Turtle Symposium (WATS II), Mayagüez, Puerto Rico.
11. Antigua and Barbuda Fisheries Regulations of 1990 (Section 21 of The Fisheries Act, 1983). Available from: http://www.fisheries.gov.ag/information/laws_regulations/pdf/Fisheries_Regulations_1990.pdf (accessed July 2013).
12. Joseph, D., Fuller, J. & Camacho, R. (1984) National Report for Antigua & Barbuda. *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 12-29. RSMAS Printing, Miami.
13. Fuller, J.E., Eckert, K.L. & Richardson, J.I. (1992) *WIDECAST Sea Turtle Recovery Action Plan for Antigua and Barbuda*. CEP Technical Report No. 16. UNEP Caribbean Environment Programme, Kingston, Jamaica.
14. Bräutigam, A. & Eckert, K.L. (2006) *Turning the tide: exploitation, trade and management of marine turtles in the Lesser Antilles, Central America, Colombia and Venezuela.* TRAFFIC International, Cambridge, UK.
15. Native Title Act 1993 (Section 211). Available from: http://www.austlii.edu.au/au/legis/cth/consol_act/nta1993147/ (accessed July 2013).
16. Limpus, C.J. (2008) *A biological review of Australian marine turtles. 2. Green Turtle* Chelonia mydas *(Linnaeus).* Queensland Government Environmental Protection Agency.
17. Limpus, C.J. (2008) *A biological review of Australian marine turtles. 1. Loggerhead Turtle* Caretta caretta *(Linnaeus)*. Queensland Government Environmental Protection Agency.
18. Harris, A., Dews, G., Poiner, I. & Kerr, J. (1994) *The traditional and island based catch of the Torres Strait Protected Zone.* Final Report on CSIRO Research 1990-1993. Final report to the Scientific Advisory Committee of the Torres Strait Protected Zone. CSIRO Division of Fisheries.
19. Skewes, T.D., Kingston, A.G., Jacobs, D.R., Pitcher, C.R., Bishop, M., Burridge, C.M. & Lilly, S. (2002) *The traditional fisheries catch of Torres Strait Islanders*. Project Final Report, 1996 - 2001. AFMA/CSIRO Division of Marine Research, Canberra.
20. Harris, A.N.M., Bishop, M., Skewes, T.D., Dews, G. & Pitcher, C.R. (1997) *Transfer of traditional fisheries monitoring in Torres Strait to AFMA, with training.* Report on CSIRO research 1993-1996. CSIRO Division of Marine Research.

21. Smith, A. (1989) *Usage of Marine Resources by Aboriginal Communities on the East Coast of Cape York Peninsula*. Great Barrier Reef Marine Park Authority, Townsville.
22. Limpus, C.J. (2009) *A biological review of Australian marine turtles. 3. Hawksbill Turtle,* Eretmochelys imbricata *(Linnaeus)*. Queensland Government Environmental Protection Agency.
23. Henry, G.W. & Lyle, J.M. (2003) *The National Recreational and Indigenous Fishing Survey*. Final Report to the Fisheries Research & Development Corporation and the Fisheries Action Program. Project No. 1999/158. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra.
24. Limpus & Reed 1985 in Groombridge, B. & Luxmoore, R. (1989) *The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade*. CITES Secretariat of the Convention on International Trade in Endangered Species of Wild Flora and Fauna, Cambridge.
25. Kennett, R., Mununggurritj, N. & Yunupingu, D. (1998) The Dhimurru Miyapunu Project. *Marine turtle conservation and management in northern Australia, Proceedings of a workshop held at the Northern Territory University, Darwin, 3–4 June 1997* (ed. by R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill), pp. 69-75. Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.
26. Hope, R. & Smit, N. (1998) Marine Turtle Monitoring in Gurig National Park and Cobourg Marine Park. *Marine Turtle Conservation and Management in Northern Australia, Proceedings of a Workshop held at the Northern Territory University, Darwin, 3–4 June 1997* (ed. by R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill), pp. 53-62. Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.
27. Whiting, S., Guinea, M. & Pike, G.D. (2000) Sea turtle nesting in the Australian Territory of Ashmore and Cartier Islands, eastern Indian Ocean. *Sea turtles of the Indo-Pacific: Research, Management and Conservation* (ed. by N.J. Pilcher and G. Ismail), pp. 86-93. ASEAN Academic Press, London.
28. Limpus, C.J., Zeller, D., Kwan, D. & MacFarlane, W. (1989) Sea-turtle Rookeries in North-western Torres Strait. *Australian Wildlife Research*, **16**, 517-525.
29. Belize Fisheries Act, Chapter 210, Revised Edition 2003. Available from: http://www.belizelaw.org/web/lawadmin/index2.html (accessed July 2013).
30. Miller, G.W. (1984) The National Report for the Country of Belize. *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 41-48. RSMAS Printing, Miami.
31. Gillette, V. (1987) *The National Report for the Country of Belize*. Prepared for the Second Western Atlantic Turtle Symposium (WATS II), 12-16 October 1987, Mayagüez, Puerto Rico. Doc. 091.
32. Smith, G.W., Eckert, K.L. & Gibson, J.P. (1992) *WIDECAST Sea Turtle Recovery Action Plan for Belize*. CEP Technical Report No. 18. UNEP Caribbean Environment Programme, Kingston.
33. Searle, L.A.W. (2004) A Brief History of Sea Turtle Communities, Conservation and Consumption in Belize. *Proceedings of the Twenty-First Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-528* (ed. by M.S. Coyne and R.D. Clark), pp. 316-318. National Marine Fisheries Service, Miami.
34. Belize Fisheries Department (2005) *Inter-American Convention for the Protection and Conservation of Sea Turtles [Belize] 2005 Annual Report*. Available from: http://www.iacseaturtle.org/informes.htm (accessed December 2012).
35. Virgin Islands Fisheries Regulations 2003, Part IV, Section 22. Available from: http://www.bviddm.com/document-center/S.I.%20No.%2020%20of%202003-Fisheries%20Regulations.pdf (accessed July 2013).
36. Fletemeyer, J. (1984) National Report for the British Virgin Islands. *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 70-117. RSMAS Printing, Miami.
37. Hastings, M. (1992) *Survey of hawksbill/green turtle nesting sites in 1990 and 1991 in the British Virgin Islands*. Technical Report No. 13. In Technical Report No. 13. Conservation and Fisheries Department, Ministry of Natural Resource and Labour
38. Winston Leonard pers.comm. in Eckert, K.L., Overing, J.A. & Lettsome, B.B. (1992) *WIDECAST Sea Turtle Recovery Action Plan for the British Virgin Islands.* CEP Technical Report No. 15. UNEP Caribbean Environment Programme, Kingston, Jamaica.
39. Davies 1991 in Eckert, K.L., Overing, J.A. & Lettsome, B.B. (1992) *WIDECAST Sea Turtle Recovery Action Plan for the British Virgin Islands.* CEP Technical Report No. 15. UNEP Caribbean Environment Programme, Kingston, Jamaica.

40. M. Hastings & A. Pickering pers. comm. in Godley, B.J., Broderick, A.C., Campbell, L.M., Ranger, S. & Richardson, P. (2004). *An assessment of the status and exploitation of marine turtles in the United Kingdom Overseas Territories in the Wider Caribbean*. Final project report for the Department of Environment, Food and Rural Affairs and the Foreign and Commonwealth Office.
41. Marine Conservation (Turtle Protection) Regulations (2008 Revision). Available from: http://gazettes.gov.ky/sites/default/files/gazette-supplements/Gs402008_web.pdf (accessed July 2013).
42. Milliken, T. & Tokunaga, H. (1987) *The Japanese sea turtle trade, 1970-1986. A Special Report prepared by TRAFFIC (Japan)*. The Center for Environmental Education, Washington D. C.
43. Parsons, J. (1984) National Report for Cayman Islands. *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 118-122. RSMAS Printing, Miami.
44. Parsons, J. (1987) *National Report to WATS II for the Cayman Islands*. Prepared for the Second Western Atlantic Turtle Symposium (WATS II), 12-16 October 1987, Mayagüez, Puerto Rico. Doc. 069.
45. Decreto Exento No. 225 (1995). Available from: http://www.sernapesca.cl/index.php?option=com_remository&Itemid=246&func=startdown&id=6215 (accessed July 2013).
46. Frazier, J.G. (1990) Marine turtles in Chile: an update. *Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-278* (ed. by T.H. Richardson, J.I. Richardson and M. Donnelly), pp. 39-41. National Marine Fisheries Service, Miami.
47. Frazier, J.G. & Brito Montero, J.L. (1990) Incidental Capture of Marine Turtles by the Swordfish Fishery at San Antonio, Chile. *Marine Turtle Newsletter*, **49**, 8-13.
48. Azócar, J.R., Olguín, A.I. & Gálvez, P.G. (2011) *Consultoría Nacional: Diagnóstico sobre tortugas marinas en Chile*. Instituto de Fomento Pesquero, Valparaiso.
49. Article 5 and Article 31, Decreto 1608 de 1979. Available at: http://www.minambiente.gov.co/documentos/dec_1608_310778.pdf (accessed July 2013).
50. Mast 1987 in Rueda, A.J.V. (1987) *National Report to WATS II for Colombia*. Prepared for the Second Western Atlantic Turtle Symposium (WATS II), 12-16 October 1987, Mayagüez, Puerto Rico. Doc. 060.
51. Rincón-Díaz, M.P. & Rodríguez-Zárate, C.J. (2003) *Caracterización de playas de anidación y zonas de alimentación de Tortugas marinas en el archipiélago de san bernardo, caribe colombiano*. Fundación Universidad De Bogota Jorge Tadeo Lozano, Bogotá.
52. Córdoba and López 1997 in Dirección General de Ecosistemas (2002) *Programa Nacional para conservación de las tortugas marinas y continentales en Colombia*. Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Bogotá.
53. Instituto Humboldt 2000 in Dirección General de Ecosistemas (2002) *Programa Nacional para conservación de las tortugas marinas y continentales en Colombia*. Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Bogotá.
54. White, M. (2012) *Monitoring the distribution, population structure and status of sea turtles in the Cook Islands*. Cook Islands Turtle Project: 2011 Annual Report. Pacific Islands Conservation Initiative, Rarotonga.
55. Hauser, N. (2001) *Cook Islands Turtle Survey*. Available at: http://www.whaleresearch.org/turtles/results2000.htm (accessed 28th January 2011).
56. Hurtado, M. (1981) Cierre de Exportaciones de Pieles de tortugas marinas en Ecuador. *Instituto Nacional de Pesca Boletin Informativo*, **2**, 1-5.
57. Gómez-Cubillos, M.C. (2010) *Sea turtle by catch in the buffer zone of Gorgona national park, Cauca state, Colombian Pacific*. In. Research Center for the Environmental Management and Development (CIMAD)
58. Forestry and Wildlife Act, Chapter 60:02, Act 12 of 1990, Section 21, Ninth Schedule. Available from: http://www.dominica.gov.dm/laws/chapters/chap60-02.pdf (accessed July 2013).
59. Franklin, A., Byrne, R. & Eckert, K.L. (2004) *2003 Annual Report: Rosalie Sea Turtle Initiative (RoSTI)*. Prepared by WIDECAST for the Ministry of Agriculture and the Environment (Forestry, Wildlife and Parks Division). WIDECAST, Roseau, Dominica.
60. Byrne, R. (2006) *2006 Annual Project Report: Rosalie Sea Turtle Initiative (RoSTI)*. Prepared by WIDECAST for the Ministry of Agriculture and the Environment (Forestry, Wildlife and Parks Division). WIDECAST, Roseau, Dominica.
61. Stapleton, S.P. & Eckert, K.L. (2007) *Nesting ecology and conservation biology of marine turtles in the Commonwealth of Dominica, West Indies: RoSTI 2007 Annual Project Report*. Prepared by

WIDECAST for the Ministry of Agriculture and the Environment (Forestry, Wildlife and Parks Division). WIDECAST, Roseau, Dominica.

62. Harris, E.H. & George, S. (2008) *Nesting Ecology and Conservation of Marine Turtles in the Commonwealth of Dominica, West Indies: 2008 Annual Project Report* (ed. by K.L. Eckert). Prepared by the Dominica Sea Turtle Conservation Organization (DomSeTCO), in partnership with WIDECAST, for the Ministry of Agriculture, Fisheries and Forestry (Forestry, Wildlife and Parks Division). DomSeTCO, Roseau, Dominica.
63. Harris, A., Errol, H., Eckert, K.L. & Harris, M. (2009) *Nesting Ecology and Conservation Biology of Marine Turtles in the Commonwealth of Dominica, West Indies: 2009 Annual Project Report*. Prepared by DomSeTCO for the Ministry of Agriculture, Forestry (Forestry, Wildlife and Parks Division). West Indies. . DomSeTCO, Roseau, Dominica.
64. Harris, A., Errol, H., Stapleton, S. & Harris, M. (2010) *Nesting Ecology and Conservation of Marine Turtles in the Commonwealth of Dominica, West Indies: 2010 Annual Project Report*. Prepared by the Dominica Sea Turtle Conservation Organization Inc. (DomSeTCO) for the Ministry of Agriculture, Fisheries and Forestry (Forestry, Wildlife and Parks Division). DomSeTCO, Roseau, Dominica.
65. Harris, A., Errol, H., Stapleton, S. & Harris, M. (2011) *Nesting Ecology and Conservation of Marine Turtles in the Commonwealth of Dominica, West Indies: 2011 Annual Project Report*. Prepared by the Dominica Sea Turtle Conservation Organization Inc. (DomSeTCO) for the Ministry of Agriculture, Fisher-ies and Forestry (Forestry, Wildlife and Parks Division). DomSeTCO, Roseau, Dominica.
66. Maison, K.A., Kinan-Kelly, I. & Frutchey, K.P. (2010) *Green turtle nesting sites and sea turtle legislation throughout Oceania*. U.S. Dep. Commerce, NOAA Technical Memorandum. NMFS-F/SPO-110.
67. Buden, D.W. (2010) Reptiles of Ngulu Atoll, Yap State, Federated States of Micronesia. *Pacific Science*, **64**, 473–480.
68. Buden, D.W. & Edward, A. (2001) Abundance and Utilization of Sea Turtles on Pohnpei, Federated States of Micronesia: Islanders' Perceptions. *Micronesica*, **34**, 47–54.
69. Cruce, J. (2009) Monitoring of nesting green turtles (Chelonia mydas) in Ulithi Atoll, Yap, Federated States of Micronesia. *Testudo*, **7**, 38-48.
70. Fisheries (Protection of Turtles) (Amendment) Regulations 2010. Available from: http://faolex.fao.org/docs/pdf/fij110378.pdf (accessed July 2013).
71. FAO Catch Statistics in Groombridge, B. & Luxmoore, R. (1989) *The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade*. CITES Secretariat of the Convention on International Trade in Endangered Species of Wild Flora and Fauna, Cambridge.
72. Limpus, C.J. (1997) Marine turtle populations of Southeast Asia and the western Pacific Region: Distribution and status. *Proceedings of the Workshop on Marine Turtle Research and Management in Indonesia. Jember, East Java, November 1996* (ed. by Y.R. Noor, I.R. Lubis, R. Ounsted, S. Troeng and A. Abdullah). Wetlands International/PHPA/Environment Australia.
73. Guinea, M. (1993) *Sea turtles of Fiji.* South Pacific Regional Environment Programme, Apia.
74. Daly, T. (1990) The development of a regional sea turtle program in the South Pacific. *Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-278* (ed. by T.H. Richardson, J.I. Richardson and M. Donnelly), pp. 169-172. National Marine Fisheries Service, Miami.
75. Daly, T. (1991) Fiji Bans Export of Turtle Shell. *Marine Turtle Newsletter*, **52**, 1.
76. Laveti, M. & MacKay, K.T. (2009) Does Fiji's Turtle Moratorium Work? *Marine Turtle Newsletter*, **123**, 12-15.
77. Fisheries Amendment Regulation 2001 SRO2, Section 17. Available from: http://www.mylexisnexis.co.za/grenada/default.asp?/qlfub/0m7jc/1m7jc/2m7jc/3m7jc/v8dkc/svukc/wbvkc/6bvkc (accessed July 2013).
78. Finlay, J. & Williams, P. (1984) National Report for Grenada. *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 184-196. RSMAS Printing, Miami.
79. Finlay, J. (1987) *National Report for Grenada*. 12 October 1987. Prepared for the Second Western Atlantic Turtle Symposium, 12–16 October 1987, Mayagüez, Puerto Rico. WATS2 056.
80. Grazette, S., Horrocks, J.A., Phillip, P.E. & Isaac, C.J. (2007) An assessment of the marine turtle fishery in Grenada, West Indies. *Oryx*, **41**, 330–336.
81. Pritchard and Suárez, 1996 in Reichart, H., Kelle, L., Laurent, L., van de Lande, H.L., Archer, R., Charles, R. & Lieveld, R. (2003) *Regional Sea Turtle Conservation Program and Action Plan for the Guianas* (ed. by K.L. Eckert and M. Fontaine). World Wildlife Fund – Guianas Forests and

Environmental Conservation Project, Paramaribo. WWF technical report no. GFECP#10. WWF, Paramaribo.

82. Victor, J.A. (1995) *Code des lois Haitiennes de l'environnment*. Projet PNUD/ECMU/HAI/92/001. UNDP, Port-au-Prince.
83. Government of Haiti (1984) National Report for Haiti. *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K.A. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 216-219. RSMAS Printing, Miami.
84. Ottenwalder, J.A. (1996) The current status of sea turtles in Haiti. *Contributions To West Indian Herpetology 12* (ed. by R. Powell and R.W. Henderson), pp. 381-393. Society for the Study of Amphibians and Reptiles.
85. ILO Convention Nº 169. Available from: http://www.ilo.org/dyn/normlex/en/f?p=1000:11200:0::NO::P11200_COUNTRY_ID:102675 (accessed July 2013).
86. Cruz, G.A. & Espinal, M. (1987) *National Report to WATS II for Honduras.* Prepared for the Second Western Atlantic Turtle Symposium (WATS II), 12-16 October 1987, Mayagüez, Puerto Rico. Doc. 022.
87. Chacón, D. (2002) *Diagnóstico sobre el comercio des las tortugas marinas y sus derivados en el istmo centroamericano*. Red Regional para la Conservación de las Tortugas Marinas en Centroamérica (RCA), San José, Costa Rica.
88. Government Regulation No. 7, 1999. Available from: http://www.setneg.go.id/index.php?option=com_perundangan&id=3223&task=detail&catid=3&Itemid=42&tahun=1999 (accessed July 2013).
89. Dethmers, K. (2010) *Ecology and phylogeography of Australasian green turtle (Chelonia mydas) populations: a case study for conservation from Aru, Indonesia*. PhD Thesis, Radboud University Nijmegen.
90. Schulz, J.P. (1987) *Observations on sea turtles in Indonesia.* Report to the IUCN Conservation Monitoring Center.
91. Halim, M.H., Silalahi, S. & Sugarjito, J. (2001) Conservation and utilisation trend of marine turtles in Indonesia. *Tigerpaper*, **28**, 10-18.
92. Suárez, A. (2000) The sea turtle harvest in the Kai Islands, Indonesia. *Sea Turtles of the Indo-Pacific: Research, Management and Conservation* (ed. by N.J. Pilcher and G. Ismail), pp. 3-12. ASEAN Academic Press, Ltd., London.
93. Dethmers, K. (2000) The Need for Co-Operation in Conservation of SE Aru Turtles. *Sea Turtles of the Indo-Pacific: Research, Management and Conservation* (ed. by N.J. Pilcher and G. Ismail), pp. 107-115. ASEAN Academic Press, Ltd, London.
94. ProFauna Indonesia (2005) Hawksbill trade in Indonesia. ProFauna Indonesia. Available from: http://www.profauna.org/download/publication/hawksbill-trade-in-indonesia-(2003).pdf
95. ProFauna Indonesia (2005) Final Report on the Sea Turtle Trade on the South Coast of Java. In. ProFauna Indonesia
96. Suarez, M. & Starbird, C. (1995) A Traditional Fishery of Leatherback Turtles in Maluku, Indonesia. *Marine Turtle Newsletter*, **68**, 15-18.
97. Lawalata, J., Hitipeuw, C., Ratnawati, N., Utra, D., Ukru, I., Maturbongs, W., Saija, G. & WWF-Indonesia (2005) Community based management of leatherbak turtles residing in Kei Islands: reducing mortality due to traditional hunting practices. *Proceedings of the Second Western Pacific Sea Turtle Cooperative Research and Management Workshop. Volume 1: West Pacific Leatherback and Southwest Pacific Hawksbill Sea Turtles. 17-21 May 2004, Honolulu, HI* (ed. by I. Kinan). Western Pacific Regional Fishery Management Council, Honolulu.
98. Hitipeuw, C., Windia Adnyana, I.B., Suprapti, D. & Andar, R. (2013) Sea turtle trade in Indonesia: Current magnitude and new mode of operation. *Proceedings of the Thirty-Third Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NOAA NMFS-SEFSC-645* (ed. by T. Tucker, L. Belskis, A. Panagopoulou, A. Rees, M. Frick, K. Williams, R. Leroux and K. Stewart), pp. 103-104. National Marine Fisheries Service, Miami.
99. Tokyo Fisheries Regulations. Available from: http://www.reiki.metro.tokyo.jp/reiki_honbun/ag10110891.html (accessed July 2013).
100. Wildlife Conservation Ordinance 1998, Chapter 100. Available from: http://www.environment.gov.ki/?page_id=47 (accessed July 2013).
101. Balazs, G.H. (1995) Status of sea turtles in the Central Pacific Ocean. *Biology and Conservation of Sea Turtles. Revised Edition* (ed. by K.A. Bjorndal), pp. 243-252. Smithsonian Institution Press, Washington D.C.

102. Pierce, R.J., Etei, T., Kerr, V., Saul, E., Teatata, A., Thorsen, M. & Wragg, G. (2006) Phoenix Islands Conservation Survey and Assessment of Restoration Feasibility: Kiribati. Conservation International and Pacific Islands Initiative. In. Auckland University, Auckland.
103. Zahir, H. (2006) Status of leatherback turtles in Maldives. *Assessment of the conservation status of the Leatherback turtle in the Indian Ocean and South East Asia, including consideration of the impacts of the December 2004 tsunami on turtles and turtle habitats* (ed. by M. Hamann, C.J. Limpus, G. Hughes, J.A. Mortimer and N.J. Pilcher), pp. 83-85. IOSEA Marine Turtle MoU Secretariat, Bangkok.
104. Frazier, J.G., Salas, S. & Didi, N.T.H. (2000) Marine turtles in the Maldive Archipelago. *Maldives Marine Research Bulletin* (ed. by J.G. Frazier, S. Salas and N.T.H. Didi), pp. 6-41. Marine Research Centre, Malé.
105. Zahir, H. (2000) Status of Sea Turtles in the Maldives. *Maldives Marine Research Bulletin* (ed. by J.G. Frazier, S. Salas and N.T.H. Didi), pp. 43-62. Marine Research Centre, Malé.
106. Marine Resource Act 1997. Available from: http://www.paclii.org/mh/legis/consol_act_new/fa110/ (accessed July 2013).
107. McCoy, M.A. (2004) *Defining parameters for sea turtle research in the Marshall Islands*. NOAA Administrative Report AR-PIR-08-04. National Oceanic and Atmospheric Administration. In, p. 92. National Marine Fisheries Service, Pacific Islands Region.
108. Rudrud, R.W., Kroeker, J.W., Leslie, H.Y. & Finney, S.S. (2007) The sea turtle wars: Culture, war and sea turtles in The Republic of the Marshall Islands. *SPC Traditional Marine Resource Management and Knowledge Information* **21**, 3-29.
109. Vander Velde, N. (2008) A Sea Turtle Genetic Sampling, Data Collection and Analysis Project in the Marshall Islands. In. Women United Together in the Marshall Islands (WUTMI), Majuro.
110. Puleloa and Kilma, 1992 in McCoy, M.A. (2004) *Defining parameters for sea turtle research in the Marshall Islands*. NOAA Administrative Report AR-PIR-08-04. National Oceanic and Atmospheric Administration. In, p. 92. National Marine Fisheries Service, Pacific Islands Region.
111. Turtle Ordinance Cap. 112 of 24 September 1951. Available from http://faolex.fao.org/docs/pdf/msr17891.pdf (accessed July 2013).
112. Martin, C.S., Jeffers, J. & Godley, B.J. (2005) The status of marine turtles in Montserrat (Eastern Caribbean). *Animal Biodiversity and Conservation*, **28.2**, 159–168.
113. Jeffers, J. (1987) Report for Marine Turtle Survey in Montserrat: 1986-1987. Prepared for the Second Western Atlantic Turtle Symposium (WATS II), 12-16 October 1987, Mayagüez, Puerto Rico. Doc. 059. In:
114. Article 2 of Mexico's Political Constitution. Available from: http://www.juridicas.unam.mx/infjur/leg/constmex/pdf/consting.pdf (accessed July 2013).
115. Foreign Affairs Secretariat (2011) *Inter-American Convention for the Protection and Conservation of Sea Turtles [Mexico] 2011 Annual Report*. Available from: http://www.iacseaturtle.org/informes.htm.
116. Márquez, M.R. (1984) National Report for Mexico (Caribbean). *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 300-309. RSMAS Printing, Miami.
117. Márquez, M.R. (1984b) National Report for Mexico (Gulf). *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 310-321. RSMAS Printing, Miami.
118. Gardner, S.C. & Nichols, W.J. (2001) Assessment of Sea Turtle Mortality Rates in the Bahía Magdalena Region, Baja California Sur, México. *Chelonian Conservation and Biology*, **4**, 197–199.
119. Nichols, W.J. (2003) *Biology and conservation of sea turtles in Baja California, Mexico*. Doctor of Philosophy with a major in wildlife ecology. University of Arizona, Tucson.
120. Koch, V., Nichols, W.J., Peckhamb, H. & Toba, V.d.l. (2006) Estimates of sea turtle mortality from poaching and bycatch in Bahía Magdalena, Baja California Sur, Mexico. *Biological Conservation*, **128**, 327 – 334.
121. Peckham, S.H., Maldonado-Diaz, D., Koch, V., Mancini, A., Gaos, A., Tinker, M.T. & Nichols, W.J. (2008) High mortality of loggerhead turtles due to bycatch, human consumption and strandings at Baja California Sur, Mexico, 2003 to 2007. *Endangered Species Research*, **5**, 171–183.
122. Mancini, A., Senko, J., Borquez-Reyes, R., Póo, J.G., Seminoff, J.A. & Koch, V. (2011) To poach or not to poach an endangered species: elucidating the economic and social drivers behind illegal sea turtle hunting in Baja California Sur, Mexico. *Human Ecology*, **39**, 743-756.

123. Alvarado, J. & Figueroa, A. (1987) *The ecological recovery of sea turtles of Michoacán, México. Special attention: the black turtle,* Chelonia agassizii. WWF-U.S and U.S Fish and Wildlife Service, New Mexico.
124. Alvarado-Díaz, J., Delgado-Trejo, C. & Suazo-Ortuño, I. (2001) Evaluation of the Black Turtle Project in Michoacán, México. *Marine Turtle Newsletter*, **92**, 4-7.
125. Cantú, J.C. & Sanchez, M.A. (2001) *History of the hawksbill trade in Mexico*. Teyeliz, A.C.
126. Cantú, J.C. & Sanchez, M.E. (1999) *Trade in sea turtle products in Mexico*. Unpublished report. Teyeliz A.C.
127. Foreign Affairs Secretariat (2011) *Inter-American Convention for the Protection and Conservation of Sea Turtles [Mexico] 2011 Annual Report*. Available from: http://www.iacseaturtle.org/informes.htm.
128. Rose, D.A. (1993) *The politics of Mexican wildlife: conservation, development, and the international system*. Doctor of Philosophy, University of Florida, Gainesville.
129. Hernandez and Aguilar, 1989 in Rose, D.A. (1993) *The politics of Mexican wildlife: conservation, development, and the international system*. Doctor of Philosophy, University of Florida, Gainesville.
130. Aylesworth, A. (2009) *Oceania regional assessment: Pacific island fisheries and interactions with marine mammals, seabirds, and sea turtles*. Project GloBAL, Beaufort, North Carolina. Available from http://bycatch.env.duke.edu (accessed October 2010).
131. Délibération n° 10167-2009/DENV/CM. http://www.juridoc.gouv.nc/JuriDoc/JdJ200.nsf/JoncP/2009-08471/$File/2009-8471.pdf?openElement (accessed July 2013).
132. Délibération n° 344 du 4 janvier 2008 relative à la protection des tortues marines. http://www.juridoc.gouv.nc/juridoc/jdtextes.nsf/(web-All)/42A6675371DCB7554B2574CE0077FC91/$File/Deliberation_344_du_04-01-2008_ChG.pdf (accessed July 2013).
133. Limpus, C.J., Boyle, M. & Sunderland, T. (2006) New Caledonian Loggerhead Turtle Population assessment: 2005 Pilot Study. *Proceedings of the Second Western Pacific Sea Turtle Cooperative Research and Management Workshop. Volume II: North Pacific Loggerhead Sea Turtles. March 2-3, 2005. Honolulu, HI* (ed. by I. Kinan), pp. 77-92. Western Pacific Regional Fishery Management Council, Honolulu.
134. Ley de Pesca y Acuicultura Nº 489 (2004). Available from: http://legislacion.asamblea.gob.ni/Normaweb.nsf/($All)/1A666D4D9929B0F6062570A100583F5F (accessed July 2013).
135. Decreto Nº 9-2005 Reglamento de la Ley Nº 489 (2005). Available from: http://legislacion.asamblea.gob.ni/normaweb.nsf/d0c69e2c91d9955906256a400077164a/824ee302eb60d1c0062570a60067a3df?OpenDocument (accessed July 2013).
136. Lagueux, C.J. (1998) *Marine turtle fishery of Caribbean Nicaragua: human use patterns and harvest trends*. Doctor of Philosophy, University of Florida, Gainesville.
137. Arostegui Montiel, R. (1984) National Report for Nicaragua. *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 337-343. RSMAS Printing, Miami.
138. Montenegro Jiménez 1992 in Lagueux, C.J. (1998) *Marine turtle fishery of Caribbean Nicaragua: human use patterns and harvest trends*. Doctor of Philosophy, University of Florida, Gainesville.
139. Lagueux, C.J., Campbell, C. & McCoy, M.A. (2003) Nesting and conservation of the hawksbill turtle, *Eretmochelys imbricata*, in the Pearly Cays, Nicaragua. *Chelonian Conservation and Biology*, **4**, 588–602.
140. Domestic Fishing Regulations 1996. Available from: http://www.spc.int/coastfish/countries/niue/RegNIUE(Eng).pdf (accessed July 2013).
141. Ruiz, A., Díaz, M. & Merel, R. (2007) *WIDECAST Plan de Acción para la Recuperación de las Tortugas Marinas de Panamá*. Informe Técnico del PAC No. 47. (ed. H.J. Guada). UNEP Caribbean Environment Programme, Kingston.
142. García, V.F.A. (1987) *National Report to WATS II for Panama.* Prepared for the Second Western Atlantic Turtle Symposium (WATS II), 12-16 October 1987, Mayagüez, Puerto Rico. Doc. 022.
143. PROMAR 1998 in Bräutigam, A. & Eckert, K.L. (2006) *Turning the tide: exploitation, trade and management of marine turtles in the Lesser Antilles, Central America, Colombia and Venezuela.* TRAFFIC International, Cambridge, UK.
144. Ordoñez, C., Meylan, A., Meylan, P., Ruíz, A. & Troëng, S. (2004) *2003 Hawksbill turtle (*Eretmochelys imbricata*) research and population recovery at Chiriqui beach and Escudo de Veraguas Island, Ñö Kribo region, Ngöbe-Buglé Comarca, and Bastimientos Island National Marine Park*. Caribbean Conservation Corporation, Gainesville.

145. Ordoñez, C., Troëng, S., Meylan, A., Meylan, P. & Ruíz, A. (2007) Chiriqui Beach, Panama, the most important Leatherback nesting beach in Central America. *Chelonian Conservation and Biology*, **6**, 122-126.
146. Diaz, E. (1984) National Report for Panama. *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 344-348. RSMAS Printing, Miami.
147. Richard 1998 in Ordoñez, C., Lahanas, P.N. & Ceballos, L. (2002) Marine turtle nesting in the Bocas del Tora Archipelago, Panama. *Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memo. NMFS-SEFSC-477* (ed. by A. Mosier, Allen Foley, and Beth Brost), pp. 96-99. NOAA, Florida.
148. Lahanas 1999 in Ordoñez, C., Lahanas, P.N. & Ceballos, L. (2002) Marine turtle nesting in the Bocas del Tora Archipelago, Panama. *Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memo. NMFS-SEFSC-477* (ed. by A. Mosier, Allen Foley, and Beth Brost), pp. 96-99. NOAA, Florida.
149. Ordoñez 2000 in Ordoñez, C., Lahanas, P.N. & Ceballos, L. (2002) Marine turtle nesting in the Bocas del Tora Archipelago, Panama. *Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memo. NMFS-SEFSC-477* (ed. by A. Mosier, Allen Foley, and Beth Brost), pp. 96-99. NOAA, Florida.
150. PNC Title 24, Chapter 12. Available from: http://faolex.fao.org/docs/pdf/pau5135.pdf (accessed July 2013).
151. Guilbeaux, M.D. (2001) *Relating to sea turtles, their management and policy in the Republic of Palau: An assessment of stakeholder perception Volumes 1 and 2*. Technical Report. Palau Conservation Society, Koror.
152. Matthews, E. (2005) *Use and consumption of marine turtles in Palau, Micronesia*. Palau Conservation Society, Koror.
153. Kinch, J. (2006) *A socio-economic assessment study for the Huon coast*. Western Pacific Regional Fishery Management Council, Honolulu.
154. Eaton and Sinclair 1981 in Groombridge, B. & Luxmoore, R. (1989) *The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade*. CITES Secretariat of the Convention on International Trade in Endangered Species of Wild Flora and Fauna, Cambridge.
155. Kwan, D. (1989) *Torres Strait Turtle Project*. Volume 1. The status of the Daru turtle fishery from October 1984 to December 1987: with implications and recommendations for management and conservation. Papua New Guinea, Department of fisheries and marine resources Port Moresby.
156. Kwan, D. (1991) The artisanal sea turtle fishery in Daru, Papua New Guinea. *Sustainable development for traditional inhabitants of the Torres Strait region: Proceedings of the Torres Strait Baseline Study Conference, Kewarra Beach, Cairns, Queensland. Workshop Series No. 16, D* (ed. by D. Lawrence and T. Cansfield-Smith), pp. 239-240. Great Barrier Reef Marine Park Authority, Townsville.
157. Eley, T.J. (1989) Sea turtles and the Kiwai, Papua New Guinea. *Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Technical Memorandum NMFS-SEFC-232* (ed. by S.A. Eckert, K.L. Eckert and T.H. Richardson), pp. 49-51. National Marine Fisheries Service, Miami.
158. Kare, B.D. (1995) A review on the research and fisheries of barramundi, reef fish, dugongs, turtles and Spanish mackerel in the Papua New Guinea side of the Torres Strait. *Joint FFA/SPC workshop on the management of South Pacific inshore fisheries*. South Pacific Commission, Noumea, New Caledonia.
159. Kinch, J. (1999) *Economics and environment in Island Melanesia: a general overview of resource use and livelihoods on Brooker Island in the Calvados Chain of the Louisiade Archipelago, Milne Bay Province, Papua New Guinea*. A Report Prepared for Conservation International, Papua New Guinea.
160. Rei, V. (2009) *Marine Turtle Population Landing Estimation from the Market Survey conducted in National Capital District, Port Moresby, Papua New Guinea*. Department of Environment and Conservation, Sustainable Marine Branch, Port Moresby.
161. Kinch, J., Anderson, P. & Anana, K. (2009) *Assessment of Leatherback Turtle Nesting and Consumptive Use in the Autonomous Region of Bougainville, Papua New Guinea*. Western Pacific Regional Fisheries Management Council, Honolulu.
162. Spring 1983 in Groombridge, B. & Luxmoore, R. (1989) *The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade*. CITES Secretariat of the Convention on International Trade in Endangered Species of Wild Flora and Fauna, Cambridge.

163. Kinch, J. (2002) *The development of a monitoring program for the management and sustainable use of sea turtle resources in the Milne Bay Province, Papua New Guinea*. A proposal prepared for the South Pacific Regional Environment Program, Apia, Western Samoa.
164. Laws Of Pitcairn, Henderson, Ducie And Oeno Islands Revised Edition 2001 Part III. Available from: http://www.pitcairn.pn/Laws/Vol%20I%20Cap%201-13%20Nov.pdf (accessed July 2013).
165. Groombridge, B. & Luxmoore, R. (1989) *The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade*. CITES Secretariat of the Convention on International Trade in Endangered Species of Wild Flora and Fauna, Cambridge.
166. Local Fisheries Regulations 1995. Available from: http://www.spc.int/coastfish/countries/samoa/Samoa-Local-Regs-95.pdf (accessed July 2013).
167. Zann, L.P. (1991) *The Status of Sea Turtles in Western Samoa*. FAO/UNDP SAM/89/002 Field Report No. 9. FAO.
168. Schuster, C., Robinson, A.C., Mulipola, A., Butler, D.J. & Time, S. (1994) *Status of sea turtles in western Samoa in 1994*. Available from: http://www.reefbase.org/pacific/pub_A0000004729.aspx
169. Decreto Legislativo Regional n. 3/ALRAP de 8 de Julho de 2009. Available from: http://faolex.fao.org/docs/pdf/sao119663.pdf (accessed July 2013).
170. Graff 1995a in Fretey, J. (2001) *Biogeography and Conservation of Marine Turtles of the Atlantic Coast of Africa*. CMS Technical Series Publication No.6. UNEP/CMS Secretariat, Bonn.
171. Graff 1995b in Fretey, J. (2001) *Biogeography and Conservation of Marine Turtles of the Atlantic Coast of Africa*. CMS Technical Series Publication No.6. UNEP/CMS Secretariat, Bonn.
172. Castroviejo, J., Juste, B.J., Pérez Del Val, J., R, C. & Gil, R. (1994) Diversity and status of sea turtle species in the Gulf of Guinea Islands. *Biodiversity and Conservation*, **3**, 828-836.
173. Fretey, J., Dontaine, J.-F. & Billes, A. (2001) Tortues marines de la facade atlantique de l'Afrique, genre Lepidochelys. 2. Suivi et conservation de *L. olivacea* (Eschscholtz, 1829) (Cheloni, Chelonidae) a Sao Tome et Principe. *Bulletin de la Societe Herpetologique de France*, **98**, 43-56.
174. Masolo, T. & Ramohia, P. (2010) *Review of marine turtles legislation in Solomon Islands*. In. SPREP, Apia. Available from: http://www.sprep.org/att/publication/000934_Solomon_turtle_legislation_review.pdf (accessed July 2013).
175. Broderick, D. (1998) *Subsistence hunting of marine turtles in the Solomon Islands. Patterns of resource use in Kia, Wagina and Katupika communities, Isabel and Choiseul Provinces*. Report to the Ministry of Forests, Environment and Conservation and the Ministry of Agriculture and Fisheries, Solomon Island Government.
176. Sulu, R., Hay, C., Ramohia, P. & Lam, M. (2000) The Coral Reefs of the Solomon Islands. *The Status of Coral Reefs of the World: 2000* (ed. by C. Wilkinson). Australian Institute of Marine Sciences, Townsville.
177. Ramohia 2000 in Mortimer, J.A. (2002) *Sea Turtle Biology & Conservation in the Arnavon Marine Conservation Area (AMCA) of the Solomon Islands*. The Nature Conservancy.
178. Richards, A.H., Bell, L.J. & Bell, J.D. (1994) *Inshore Fisheries Resources of Solomon Islands*. FFA Report 94/01. Forum Fisheries Agency, Honiara, Solomon Islands.
179. Skewes, T.D. (1990) *Marine Resource Profiles: Solomon Islands*. FFA REPORT 90/61. South Pacific Forum Fisheries Agency, Honiara, Solomon Islands.
180. Hassan, K. (2011) A Review of Somalia's (& Semi-Autonomous Regions) Fisheries Legislation & Management. Programme for the implementation of a regional fisheries strategy for the Eastern and Southern African and Indian Ocean Region. Smartfish Report SF/2011/11. In, p. 42
181. Anon 1986 in Groombridge, B. & Luxmoore, R. (1989) *The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade*. CITES Secretariat of the Convention on International Trade in Endangered Species of Wild Flora and Fauna, Cambridge.
182. Schleyer, M. & Baldwin, R. (1999) *Biodiversity assessment of the northern Somali coast east of Berbera*. EARO/75561/417. IUCN Eastern Africa Programme. Somali Natural Resources Management Programme
183. Galair, A.S. (2009) *RMCO sheds light on turtle harvest in Somalia*. Available at: www.ioseaturtles.org/pom_detail.php?id=86 (accessed 3rd July 2013).
184. Fisheries Regulations 1995. Available from: http://faolex.fao.org/docs/pdf/stk3082.pdf (accessed July 2013).
185. Wilkins, R. & Barret, A. (1987) National Report to WATS II for St. Kitts and Nevis. Prepared for the Second Western Atlantic Turtle Symposium (WATS II), 12-16 October 1987, Mayagüez, Puerto Rico. Doc. 055.
186. Eckert, K.L. & Honebrink, T.D. (1992) *WIDECAST Sea Turtle Recovery Action Plan for St. Kitts and Nevis*. CEP Technical Report No. 17. UNEP Caribbean Environment Programme, Kingston.

187. Barrett 1988 in Eckert, K.L. & Honebrink, T.D. (1992) *WIDECAST Sea Turtle Recovery Action Plan for St. Kitts and Nevis*. CEP Technical Report No. 17. UNEP Caribbean Environment Programme, Kingston.
188. d'Arbeau 1989 in Eckert, K.L. & Honebrink, T.D. (1992) *WIDECAST Sea Turtle Recovery Action Plan for St. Kitts and Nevis*. CEP Technical Report No. 17. UNEP Caribbean Environment Programme, Kingston.
189. Fisheries Regulations (No. 9) of 1994. Available from: http://faolex.fao.org/docs/pdf/stl5074.pdf (accessed July 1994).
190. Murray, P.A. (1984) National Report for Saint Lucia. *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 370-380. RSMAS Printing, Miami.
191. d’ Auvergne, C. & Eckert, K.L. (1993) *WIDECAST Sea Turtle Recovery Action Plan for St. Lucia*. CEP Technical Report No. 26. In. UNEP Caribbean Environment Programme, Kingston, Jamaica.
192. Bucknal 1988 in Groombridge, B. & Luxmoore, R. (1989) *The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade*. CITES Secretariat of the Convention on International Trade in Endangered Species of Wild Flora and Fauna, Cambridge.
193. Fisheries Regulations (S.R.O. No. 1) of 1987. Available from http://faolex.fao.org/docs/pdf/stv2111.pdf (accessed July 2013).
194. Grazette 2002 in Bräutigam, A. & Eckert, K.L. (2006) *Turning the tide: exploitation, trade and management of marine turtles in the Lesser Antilles, Central America, Colombia and Venezuela.* TRAFFIC International, Cambridge, UK.
195. Scott, N. & Horrocks, J.A. (1993) *WIDECAST Sea Turtle Recovery Action Plan for St. Vincent and the Grenadines*. CEP Technical Report No. 27. UNEP Caribbean Environment Programme, Kingston, Jamaica.
196. Rees, A.F., Saad, A. & Jony, M. (2010) Syria. *Sea turtles in the Mediterranean: Distribution, threats and conservation priorities* (ed. by P. Casale and D. Margaritoulise), pp. 233-244. IUCN, Gland.
197. Jony, M. & Rees, A.F. (2008) Three years of monitoring turtle nesting in Syria (2004-2006): what progress has been made towards protection? . *Proceedings of the 27th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-569* (ed. by A.F. Rees, M. Frick, A. Panagopoulou and K. Williams), pp. 238-239. National Marine Fisheries Service, Miami.
198. Balazs, G.H. (1983) Sea Turtles and Their Traditional Usage in Tokelau. *Atoll Research Bulletin*, **279**, 1-41.
199. Fisheries Management (Conservation) Regulations 2008. Available from: http://www.tongafish.gov.to/legislations.html (accessed July 2013).
200. Havea, S. & MacKay, K.T. (2009) Marine Turtle Hunting in the Ha'apai Group, Tonga. *Marine Turtle Newsletter*, 123, 15-17.
201. Fisheries Protection Ordinance & Fisheries Protection Regulations (1998). Available from: http://faolex.fao.org/docs/pdf/tci14804.pdf (accessed July 2013).
202. Fletemeyer, J. (1984) National Report for the Turks & Caicos. *Proceedings of the First Western Atlantic Turtle Symposium, 17-22 July 1983, San José, Costa Rica. Volume III: The National Reports* (ed. by P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren and M. Weber), pp. 409-422. RSMAS Printing, Miami.
203. Richardson, P., Broderick, A., Campbell, L., Godley, B. & Ranger, S. (2006) Marine turtle fisheries in the UK Overseas Territories of the Caribbean: Domestic legislation and the requirements of multilateral agreements. *Journal of International Wildlife Law and Policy*, **9**, 223–246.
204. Stringell, T., Calosso, M.C., Claydon, J.A., Clerveaux, W., Godley, B., Lockhart, K.J., Phillips, Q., Ranger, S., Richardson, P.B., Sanghera, A. & Broderick, A. (2013) Marine turtle harvest in a mixed small-scale fishery: evidence for revised management measures. *Ocean and Coastal Management*, **82**, 34-42.
205. Wildlife Conservation Act (Cap. 47) 1975. Available from: http://www.tuvalu-legislation.tv/cms/images/LEGISLATION/PRINCIPAL/1975/1975-0002/WildlifeConservationAct_1.pdf (accessed July 2013).
206. Alefaio, S., Alefaio, T. & Resture, A. (2006) *Turtle monitoring on Funafuti, Tuvalu December 4th -14th 2006*. Report of survey administered by the Institute of Marine Resources. In, p. 4. University of the South Pacific, Suva.
207. Petro, G., Hickey, F., R & Mackay, K. (2007) Leatherback Turtles in Vanuatu. *Chelonian Conservation and Biology*, **6**, 135-137.

Chapter 3: Assessing the small-scale shark fishery of Madagascar through community-based monitoring and knowledge

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Abstract

Over 90% of those employed in commercial capture fisheries work in the small-scale fisheries (SSF) sector and an estimated 97% of small scale fishers are found in developing countries. However, the capacity for monitoring SSF globally is low and there is a paucity of data, in particular for remote areas within developing nations. The methods presented here demonstrate a low cost participatory approach for gathering data on small-scale fisheries, particularly for those that are remote and scattered. Community-based data collectors were trained to record biological and socioeconomic data on the traditional (non-motorised) shark fishery in the Toliara region of Madagascar over a six year period (2007-2012). An estimated 25 species of shark were recorded of which 31% (n = 3505) were *Sphyrna lewini* (scalloped hammerhead), a species listed by the IUCN as Endangered. Although the number of sharks landed annually has not decreased during our survey period, there was a significant decrease in the average size of sharks caught. Despite multiple anecdotal reports of shark population declines, shark landings appear to have been maintained through changes in gear and increases in effort which may mask a decline in populations. The numbers of sharks taken by the traditional fishery in our study region was estimated to be between 65,000 and 104,000 year^{-1}, whilst estimates using national export and import of dried shark fin from Madagascar and shark length data in this study put total landings between 78,000 and 471,851 year^{-1}. Reliable data on the total volume of sharks landed in Madagascar's waters is scarce, in particular for foreign industrial boats both directly targeting shark species and as bycatch in fisheries targeting other species. There is currently no legislation in place to protect sharks from overexploitation in Madagascar and an urgent need to address the lack of shark fishery management across the traditional, artisanal and industrial fisheries.

Introduction

There is a paucity of information on take and bycatch from small-scale, traditional and artisanal fisheries often due to their remoteness, seasonality, and the numerous landing sites and vessels used (Salas *et al.* 2013); despite the fact that over 90% of 120 million employed in commercial capture fisheries work in this sector (Béné *et al.* 2007; World Bank/FAO/WorldFish Center 2010). Worldwide, more than one billion people rely on fish as an important source of protein, and it can account for 50% of protein intake in the least developed countries in Africa and Asia (Béné *et al.* 2006), where 97% of coastal fishing populations are found (World Bank/FAO/WorldFish Center, 2010). Studies have shown that small-scale fisheries generate a significant proportion of household income; for example accounting for 82% of household income in some regions of Madagascar (Barnes-Mauthe *et al.* 2013), highlighting the importance of sustainable management strategies.

The recorded global catch of chondrichthyans (sharks, rays and chimaeras) grew rapidly in the latter half of the 20th century, increasing from approximately 270,000 metric tonnes in 1950 to a peak over 900,000 tonnes in 2003 (FAO 2013), largely in response to the increase in the fin market in Asia (Field *et al.* 2009). However, recent estimates using shark fin market data (Clarke *et al.* 2006) suggest that FAO figures underestimate the size of the fishery by up to four times; whilst Worm *et al.* 2013 have estimated that annual shark mortality (including reported landings, dead discards and illegal, unregulated and unreported, IUU, take) from 2000 to 2010 has ranged between 1.41 and 1.44 million metric tonnes and equates to annual shark mortality of 63-273 million sharks. Sharks are landed both in small-scale and industrial fisheries. Although relative numbers on the volume of sharks landed in specific fisheries are scarce, many countries report significant landings figures from small-scale vessels (Blaber *et al.* 2009; Cartamil *et al.* 2011).

Accurate assessments of shark mortality across all fisheries are confounded by the fact that many sharks are finned at sea and discarded, discarded whole as well as subject to Illegal, Unreported and Unregulated (IUU) fishing (Biery *et al.* 2011; Worm *et al.* 2013). These factors have led to a severe underreporting at all scales of fishing activity, from direct take to bycatch (Varkey *et al.* 2010; LeManach *et al.* 2012). This underreporting and lack of official data means that managing shark fisheries presents a significant challenge, whilst threatening the long-term sustainability of these fisheries, and those that rely on them for their livelihoods and food (Shehe & Jiddawi 2002; Vieira & Tull 2008; Cartamil *et al.* 2011).

Sharks and other chondrichthyans are particularly vulnerable to overexploitation through direct take and bycatch due to their relatively slow growth and reproduction rates (Camhi *et al.* 1998), coupled with the degradation of marine habitats this has led to the decline in chondricthyan population numbers worldwide (Baum *et al.* 2003; Baum & Myers 2004; Cortes *et al.* 2006; Ferretii *et al.* 2008; Hayes *et al.* 2009). As a result, there has been an increase in the number of shark species listed on the IUCN Red List, with a quarter of species estimated to be threatened with extinction primarily due to overfishing (Dulvy *et al.* 2014; IUCN, 2015).

The status of shark fisheries in the Western Indian Ocean in particular, are poorly known (Kroese & Sauer 1998; LeManach *et al.* 2012). The rise in shark fishing in Madagascar coincided with the increase in demand for shark fins in Asia (Cooke

1997), although shark fishing was known as far back as the 1950s (Fourmanoir 1961; Cooke 1997). Recorded exports increased rapidly in the late 1980s from 3 tonnes in 1987 to almost 29 tonnes in 1992, with a concurrent rise in local price for shark fin, with the majority of exports going to Hong Kong and Singapore (Cooke 1997; Cripps *et al.* 2015). Official imports of shark fins to Hong Kong and Singapore, from Madagascar, show growth from 34.5 tonnes in 1986 to a peak of 64.7 tonnes in 1995 (Le Manach *et al.* 2011, 2012). Despite discrepancies between export and import data (Le Manach *et al.* 2011, 2012; Cripps *et al.* 2015), overall trends show export data from the *Ministère des Ressources Halieutiques et de la Pêche* (MRHP) and imports of shark fins both peaking in the early to mid-1990s and declines until the early 2000's; with increases again from 2004 (Cripps *et al.* 2015). In addition there are reports of decreases in shark landings (Laroche & Ramananarivo 1995; Mcvean *et al.* 2006) but shark fins remain a highly valuable marine resource, with the meat retained for local consumption (Cripps *et al.* 2015).

Previous studies estimate that around 30 chondricthyan species are regularly taken in Madagascar's coastal shark fisheries (Cook 1997), that are classified as traditional (local sailing boat which could include a motor) or artisanal (boat with a <50hp motor) (Ordinance No. 93-022 and Decree No. 94-122). Active shark fisheries have been highlighted along much of Madagascar's coastline, with the SW and NE regions remaining hotspots for fishing and trade of sharks and their fins (Cooke 1997; Pascal 2003; McVean *et al.* 2006; Doukakis *et al*. 2007; Robinson & Sauer 2013). For example, in two villages in SW Madagascar, it was estimated that a total of 123 tonnes of sharks were landed over a 13 month period (McVean *et al.* 2006). More recently, Le Manach *et al.* (2012) reconstructed total fisheries landings for

Madagascar and estimated that the total catch of sharks is over 8000 tonnes y^{-1} (3800 tonnes y^{-1} domestic catches and 4300 tonnes y^{-1} of catches by foreign vessels).

Here we present the first multiyear assessment of the status of the traditional (non-motorised) shark fishery in Madagascar that targets both sharks and guitarfish spp. (Rhinobatidae) primarily for their fins. This study set up a network of trained community-based data collectors in order to facilitate landings data collection over an inaccessible coastline with remote shark fisheries, whilst building capacity for participatory fisheries monitoring. The results of this study are contextualised with available information on Madagascar-wide shark catch.

Methods

Study area

The study was conducted in 24 villages in two regions on the southwest coast of Madagascar. Data collection took place in twelve villages surrounding the village of Andavadoaka (region 1; Figure 1; Table 1) (22°04′19.94″S, 43°14′20.00″E), approximately 150 km north of the regional capital of Toliara. Data collection took place in a further twelve villages and islands surrounding the village of Belo-sur-Mer (region 2; Figure 1; Table 1) (20°55'4.92"S, 44°23'25.65"E), approximately 60 km south of the city of Morondava. The study spanned over 175 km of coastline from Antsepoke in the south (22°15'50.14"S, 43°13'34.80"E) of region 1 to Ampatiky (20° 8'40.15"S, 44°22'10.55"E) in the north of region 2, as well as three offshore islands in region 2 (Nosy Be, Nosy Andravoho and Nosy Andriamitaroke) inhabited by migrant fishers. Region 1 is characterised by two distinct fringing and barrier reef systems separated by a 5 km wide channel in which are situated several patch reefs. Region 2 lies at the northern end of a 55 km long coral reef system, running roughly parallel to the shore at a distance of 10-15 km. This ancient, submerged barrier reef system, with its seven islands and associated shallow reef crests, extends over 600 km to the north.

The human populations in these coastal villages and islands are almost entirely composed of *Vezo* fishers and their families, semi-nomadic fishers who rely exclusively on the marine environment for their livelihoods (Astuti, 1995). All fishing is carried out using pirogues (small sailing canoes) or walking with nets, lines or spears, limiting most fishing effort to the nearby reef systems, with fishing at deeper, offshore sites only possible during favourable sea conditions.

The monitoring programme

To develop a profile of the shark fishery in the region, a monitoring programme was set up in region 1 in October 2006, and in region 2 in May 2008, that employed local community members as data collectors, known as “*sous-collecteurs”*, in each of the villages (Humber *et al.* 2011). Village presidents, elders or their relatives were, where possible, chosen as data collectors as they were typically in the best position to enable the monitoring programme to be accepted by the village residents.

Community members were paid a base monthly salary of 15,000 (≈US$6-8) Malagasy Ariary (MGA) and an additional 300 MGA (≈US$0.14-0.16) for each landed shark they recorded (intended to be given to the fishermen as a gift for allowing their shark to be measured). The average daily wage in the region is < US$2 and this payment acted to supplement their normal income.

Data collection

Each community member data collector was trained by the Project Coordinators and Project Assistants to record biological data, fisher demographics and catch-specific information for each shark in the initial training session (~1-2 hours) in their village. Community members were given notebooks with diagrams of measurements, and tape measures. They were also trained to use a digital camera to record catch in order to check the reliability of the data and reduce the possibility of falsified data. For each shark landed, biological data: species, pre-caudal length (PCL) (cm), pre-first dorsal length (cm) and sex were recorded, as were fisheries data: fishing site, method of capture and name of fishermen.

Shark species names were recorded by their local name in Malagasy as they can vary between villages and regions (Cooke 1997). Due to the highly diverse nomenclature for some shark species we could not draw up a comprehensive species name list with confidence for data collectors to use. In addition, from previous studies we knew the provision of a list of species meant that data collectors would try to categorise landings according to this list, even if the landed species was not found on the list (C. Gough pers. comm.).

Recorded nets used within the shark fishery were classified into four categories in this study, according to local names: *Jarifa*, a long gill net with the largest mesh between 12 and 25 cm; *Zdzd*, another long gill net that has a large mesh size of 8 to 10 cm; and *Janoky*, a smaller gill net with a smaller mesh size of 4 to 9 cm. The final category was simply categorised as *harata* (“net”) and encompasses the locally produced nets that will have mesh sizes of 2 to 5 cm.

Community members were visited every 4-8 weeks by the Project Coordinator and/or Project Assistant, to retrieve data and review data collection methods. Further training with the camera was given if photos were not of high enough quality, as well as any improvements in monitoring (eg. laminated cards showing shark species names to use in photos). The camera’s memory cards were wiped after each data collection visit so no accidental replication of photos could occur.

Data verification

Data were entered into an excel spreadsheet by Project Coordinators and Assistants and cross referenced with the original paper records (by FH). Data were removed that did not meet a strict verification process during cross-checks with digital camera records, with only confirmed original records included. Therefore 9,307 data records were removed during this process where inconsistencies between the data book and photographs were spotted, including data from two villages in region 1 (Nosy Hao and Nosy Be) removed completely. The majority of inconsistencies were the use of the same shark to create multiple photos and lines of landings data. By removing all duplicates from any month-year where duplications were spotted, we aim to have increased the robustness of these data and ensured that estimates provided are conservative. Interpolation using minimum numbers (see Section: Data interpolation) has also allowed for removed data to be included in estimates and therefore not affect overall calculations for numbers of sharks landed.

Number of sample sites

The number of villages recording data at any one time fluctuated depending on the availability of a suitable community member to collect data and changes in shark fishing activity in a particular village or island (due to seasonal fisher migrations and a decree protecting islands in Region 2 from settlement).

Table 1 shows a list of villages included in this study, their human population size, the number of sharks recorded each year and the number of months for which shark catch was recorded, between 1 January 2007 and 31 December 2012.

Data interpolation

To account for missing and removed months in data collection, the minimum month's landings for that year were used as proxy (Table 1). For the three islands (Nosy Andravoho, Nosy Andriamitaroke and Nosy Be) it was assumed that there were only 10 months of fishing/year from prior knowledge on fishing seasons on these islands. To account for removed years, we used the minimum annual landings for other years as a proxy. In region 1 data were also interpolated for years when no data collection took place (eg. Nosy Lava), because shark landings were known to occur, even though villages were no longer monitoring landings due to lack of a suitable data collectors. In region 2, data were not extrapolated for years without data collection because data collection was purposefully stopped in these villages when shark landings were negligible.

Shark fins

In larger villages and towns, shark fin ‘middle men’ exist who will buy and collect shark fins from fishermen for ~10,000 to 200,000 MGA/kg (~US$4.5 – 91.0) to sell to the next person in the value chain, normally a buyer from Asia (Cripps *et al.* 2015; fin collector pers. comm.). There are two price scales of fin quality: one for guitarfish spp. and one for all other species (Cripps *et al.* 2015). Quality ranges from 0 (best) to 4 (worst), and is based primarily on size but also colour, amounts of cartilage fibre, cut and species (Cooke, 1997; Cripps *et al.* 2015). Two shark fin middle men were also employed as part of this study, and provided data on the number, size, source, prices and quality of fins they purchased. The fins purchased by the middlemen are not necessarily from the same geographical scope as the shark landings in our study, as middlemen will purchase fins from a wider region through the use of fin collectors.

Socioeconomic interviews

In order to gain an overview of the shark fishery from the villagers' perspectives, *ad hoc* semi-structured interviews and several structured focus groups were carried out with the data collectors and shark fishermen in villages throughout the regions during the study period. All interviews and focus groups were conducted in Malagasy by the Project Coordinator and/or Assistant(s).

In January to March 2013, participative appraisals were completed using focus groups in a sample of villages in each region in order to gather ranked reasons for changes in numbers of sharks landed each year. Project assistants were trained to carry out focus groups using a consensus workshop methodology by a Blue Ventures' staff member highly experienced in social survey techniques and group facilitation.

Species identification

Although it was not possible to identify individual sharks due to photograph quality and little data existing on shark species lists and IDs for Madagascar, a subsample of photographs were sent to three experts to assist validation of certain species identifications and provide further identifications where possible. In order to collate the range of names used for species in Madagascar, workshops were held in both regions with fishers and data collectors to assemble alternatives names for each shark name featured in the data. In June and July 2012, workshops were also held with data collectors and shark fishers in both regions to map different names for local names given to species.

Length-length calculations

PCL was converted to total length (TL) in order to calculate frequency size distribution and to compare catch to minimum total lengths (TL) at maturity for scalloped hammerheads *Sphyrna lewini* and sliteye sharks *Loxodon macrorhinus*. PCL was converted to TL using length-length conversion data obtained from Fishbase.org (Table S1): TL = 0 + 1.293 x SL for sliteye sharks and Other = 0 + 0.704 x TL for scalloped hammerheads. Minimum PCL at maturity for Giant Guitarfish *Rhynchobatus djiddensis* was calculated using the formula TL = 0 + 1.118 x SL (Table S1; Fishbase.org).

National estimates of shark landings

Two methods were used to estimate national shark landings, as well as to contextualise landings and regional estimates, using data collected in this study.

1. Dried shark fin data

The number of dried shark fins recorded in this study was converted into the number of sharks by dividing by four (on average four fins are taken per shark). The total weight of these dried sharks fins was compared to the total weight of dried shark fins exported and imported to estimate the relative number of sharks.

2. Length data

First, the total wet weight of sharks represented by national export and import figures of dried fin weights from Madagascar was calculated using a conversion factor that the average yield of dried fins from shark wet weight is 1.44% (Anderson & Ahmed, 1993). Although dried fin weights from shark wet weight can vary, few studies have been published, and this is likely to be a conservative figure (Clarke et al., 2004).

Second, to estimate numbers of sharks represented by total wet weight, we used two methods to generate a range. (1) Total wet weight for import and export data were divided by 12.25 kg (the average weight recorded for sharks sampled in northern Madagascar (Robinson & Sauer, 2013). (2) In the second method, length data from our study was used to calculate the average wet weight of identified sharks in our study. The average wet weight of *Sphyrna lewini* and guitarfish spp. were calculated using the following formula: weight (g) = a × length $(cm)^b$. Calculations were made using length–weight conversion data obtained from the website FishBase.org. Values for *a* (0.0048) and *b* (3.07) were the geometric means given for *S. lewini* by FishBase. All guitarfish spp. were considered to be the giant guitarfish (*R. djidensis*) and values for *a* (0.0026) and *b* (3.05) were the only entry given by FishBase. The wet weight of 79 *L. macrorhinus* were taken in village of Andavadoaka in 2009 to 2010 was 1.63 kg ±0.55.

The aim of using these two methods to generate a range was to account for the presence of many small animals within the identified shark species within this study, and therefore any potential overestimations of shark numbers in national estimates.

Statistics

All statistical tests were carried out using the MASS package for R v.2.12.0 (R Development Core Team, 2010). To investigate the relationship between year and PCL of each shark species, we used generalized linear models (GLMs), with log transformation of PCL, and with Gamma errors and log link functions. We assessed the suitability of the models using residual diagnostic plots and goodness-of-fit metrics via the dispersion parameter.

Results

Number of sharks

A total of 11,428 landed elasmobranchs were recorded as part of this study, with a range of 923 to 2848 sharks recorded.year^{-1} (Table 1). After accounting for missing months of data we estimated total catch for these sites to be 15,457 (a range of 939 to 3833 sharks recorded.year^{-1}), with an estimated 3,017 landed in 2012. No effort was made to estimate shark landings in 2007 for region 2. These figures are likely to be the minimum elasmobranch landings for each village as all community members were not able to record every landed shark. Community members estimated that on average they were recording 60% of shark landings (n = 12, range = 16-100%, sd = 25.0). We could not adjust the landings data in relation to the percentage of landings recorded for each village as not all villages provided estimates of recording intensity.

Species

Species names were recorded in the local dialect of Malagasy due to the difficulty in shark identification. Local names for shark species can vary by village and 65 different names were recorded in this study, corresponding to approximately 25 species of elasmobranch (Table S2; Table S3). A number of ray landings were also recorded by data collectors which were not included in subsequent analyses on size. Eleven shark species and five families were identified by experts. Although it was not possible to positively ID all landed sharks, the most numerous recorded names in Malagasy correspond to two species (scalloped hammerhead *Sphyrna lewini* and sliteye *Loxodon macrorhinus*) and one family, Rhinobatidae (Guitarfish spp.), and accounted for >75% (n = 8,637) of landings recorded (Figure 2; Table S1). Within all remaining landings (n = 2,791; 24.4%), no local name accounted for >2% (region 1) or >10% (region 2) of recorded landings. Fourteen identified species and families are found on the IUCN Red List, with *S. lewini* listed as Endangered, *L. macrorhinus* Least Concern and all guitarfish species listed as Vulnerable. Seven of the remaining identified species are classified as Near Threatened, two as Vulnerable, one as Data Deficient and one family (Pristiophoridae, sawsharks) which has all species classified as Least Concern or Data Deficient (Table S2).

Scalloped hammerheads featured prominently in both regions shark fisheries (region 1 = 20.1%, n = 1,341; region 2 = 45.4%, n = 2,164), with sliteyes being the dominant landing in region 1 (56.0%, n = 3,729) although only accounting for 4.2% (n = 201) in region 2. Changes in species landings by year show increases in guitarfish spp. landings in region 1, and scalloped hammerheads and sliteyes in region 2 over the study period (Figure S2). Scalloped hammerheads increased in landings in 2012 in region 1, along with a pronounced peak in sliteye landings in 2010.

Size frequency and average wet weight

The mean and range of recorded size of scalloped hammerheads, sliteyes and guitarfish spp. are shown in Table S1. Size distribution using TL (scalloped hammerhead, sliteye) and PCL (guitarfish spp.) was strongly skewed towards smaller individuals for scalloped hammerhead and guitarfish spp., whilst skewed towards larger individuals for sliteyes (Figure 3). The dominant size class was 51-60 cm for both male and female scalloped hammerheads and it is estimated that at least 95.3% (n = 1998) of females and 10.6% (n = 1211) of males were juveniles in this study (Figure 3; Table S1). However, the majority of both female (77.6%, n = 1710) and male (94.7%, n = 1563) sliteyes recorded were mature. Fishbase.org lists four species of guitarfish spp. found in Madagascar’s waters of which *R.djiddensis* and *R. ancylostoma* have been documented in Madagascar's shark fisheries (Cook 1997, McVean *et al.* 2006, Robinson & Sauer 2013). Using available conversion data our landings would be the equivalent of 89.0% (n = 1067) juvenile *R. djiddensis*, and 78.0% (n = 936) below the maximum PCL for *R. annulatus.*

The overall average weight was estimated as 6.4 kg per shark for identified species within this study.

Size over time

There was a significant effect of year on average PCL size for scalloped hammerheads sharks ($F_{1,3441}$=1369.2, p<0.001), and PCL decreased between 2007 and 2012 from 89.3 cm to 45.1 cm (Figure 4).Year also had a significant effect on average PCL size for sliteyes ($F_{1,3869}$ = 12.076, p<0.001), guitarfish ($F_{1,1197}$ = 337.83, p<0.001) and the grouped remaining shark landings ("other") ($F_{1,2706}$ = 209.59, p<0.001) (Figure 4). Average PCL of "other" sharks decreased from 99.0 cm in 2007 to 69.4 cm in 2012. Decreases in size of sharks landed were also reported in interviews with data collectors (Table S4).

Regional estimates

The province of Toliara has an estimated 186,658 fishermen (Cornell Census 2001). The most recent data from 2012 provides a robust yet conservative estimate of the number of shark landings within two communes in the Toliara province, and an estimate of 0.21 – 0.33 sharks/fisher/year. If a similar catch rate is assumed for the remaining Toliara province fishers we estimate that 39,000 to 62,000 sharks are landed per annum in this region. If we also take into account that data collectors estimated that on average they recorded 60% of shark landings in their village, we estimate that total take in the traditional fishery in the Toliara province could range from 65,000 to 104,000 sharks per annum.

Fin numbers and quality

A total of 56,651 (total dry weight of fins was 6,425.6 kg; average fin weight 0.113 kg) fins were recorded by fin collectors over the six year study period, and represents a minimum of 14,163 sharks. For all years apart from 2011, fourth quality fins accounted for >70% of fins bought by middlemen, apart from 2011 where a 5th quality was introduced by the collector for even lower quality <10 cm fins (worth 2-3000 MGA/kg; ~ 0.89-1.3 USD/kg) and accounted for 44% of fin data. Whilst some dried shark fin data may be from sharks landed from our study region, the two sets of data can not be directly compared, due to differences in the collection area of middlemen.

National estimates

Official export figures from Madagascar show annual dried shark fin exports ranged between 31.9 and 43.3 t between 2007 and 2011, whilst annual imports from Madagascar to Hong Kong ranged between 13.9 and 29.8 t within the same period (Cripps *et al.* 2015; Ministère de la Pêche et des Ressources Halieutiques 2011). It is estimated that 90.5% of Madagascar's shark fin exports were to Hong Kong between 1999 and 2009 (Cripps *et al*. 2015).

Between 2007 and 2011, the number of dried fins recorded in this study represents a minimum of 2,562 sharks per annum. The weight of dried fins recorded in this study by fin collectors accounted for approximately 3.07% of annual national export records and 4.88% of Hong Kong import records of dried fins for the five year period 2007 to 2011. Scaled up, this could represent an annual range of 52,519 to 83,373 sharks landed; varying with the range of export and import data reported each year.

However, if we assume that dried fin weight is 1.44% of total body weight, then the dried shark fin data in this study and numbers of sharks estimated, would give 32 kg per animal. Given our data, and that previously recorded in northern Madagascar, show a range of 6.4-12.25 kg per animal, it suggests that there are many more than 14,000 animals represented in the dry fins weights recorded in this study. If it is assumed more conservatively that the average weight per shark is 12.25 kg, then the number of sharks represented by the total dried shark fin weight (6425.6 kg) is 36,426 and represents an annual range of 124,000 to 197,700 sharks.

As national estimates from dried shark fin data collected within this study seemed unrealistic, national export and import data were also used to estimate national landings of sharks. Converting national export and import data on dried fin weight to wet weight of sharks gave an annual range of 963 to 3008 metric tonnes. Using the range for average shark weight as 6.4 – 12.25 kg, annual shark landings are estimated at 78,616 to 471,851 during 2007 to 2011.

Trends in landings numbers

To assess catch trend over time, the estimated number of sharks landed by villages with long-term monitoring (minimum 8 months in each survey year in region 1; minimum 4 years monitoring in region 2) were plotted (Figure 5). Landings in region

1 increased from 2007 to 2012 with a peak in 2010 (n = 1,521). This peak was driven by high catch in one village (Lamboara) of 1,157 sharks. In region 2 there was a small increase from 2008 to 2012 with a peak in landings in 2009 (n = 1,112). Landings by village show greater variation by year (Figure S1). Interviews with data collectors and shark fishers revealed that 53% of villages (n = 9) questioned believed that there had been a decrease in the numbers of sharks available over the last five to twenty years (Table S4).

Fishing methods

Nets (gill nets) were used to land over 80% (n = 9,464) of sharks, followed by hook and line (11.7%; n = 1,338) and longline (4.3%; n = 495) across both regions (Table S5). Changes in fishing gears are apparent year by year, most notably an increase in use of smaller meshed nets (*janoky* and “net”) (Table S5).

Discussion

This paper describes a replicable method to assess the status and changes within small-scale fisheries, working with community members to directly measure shark landings. Small-scale fisheries are regularly cited as data deficient (Ehrhardt & Deleveaux, 2007; Jacquet *et al.* 2010), despite their importance for income and protein; also an issue cited in such shark fisheries (Le Manach *et al.* 2012; Alfaro-Shigueto *et al.* 2010).

The results of this study show that in terms of definitive numbers, the traditional shark fishery in southwest Madagascar has not declined between 2007 and 2012. However, the number of sharks recorded in this study across 22 villages (~1900/year) is lower than the number of sharks (1164) recorded by McVean *et al.* (2006) from two villages over a 13 month period in 2001-2002 in the SW; and could be due to differences in fishing activity in villages selected and decreases in the shark fishery from 2001 to 2007. *Sphyrna* (hammerhead) spp. also dominated the traditional shark fishery in McVean *et al.* (2006), representing 29% of sharks landed; and also 24% of catch in the artisanal shark fishery in northern Madagascar (Robinson & Sauer, 2013). Guitarfish spp. are only identified as being part of the fishery but do not seem to be caught in any significant numbers. Sliteye sharks are not listed in McVean *et al*. (2006), although are noted as part of Madagascar's shark fisheries in other reports (Cooke, 1997; Randriamiarisoa, 2008; Robinson & Sauer, 2013).

Although numbers of sharks landed did not seemingly decline during this study, declines in shark population numbers were reported during social surveys within this study. Declines in the traditional shark fishery in Madagascar were reported by the late 1990s (Cook, 1997), with fishers reporting they had to go further afield to catch sharks (Smale, 1998). Regular reports from community elders cite that in their youth large sharks were present in lagoonal areas in SW Madagascar and are no longer present. Since 2003, daily SCUBA diving in the lagoon in study region 1 by Blue Ventures has occurred and reports of shark sightings have been negligible.

Significantly smaller sharks were also landed over the study period but it is not possible to determine whether this is due to overfishing of larger individuals or changes in gear although this study shows apparent shifts from larger meshed to smaller meshed nets. Increases in fishing effort or shifts in gear use could also mask declines in the numbers taken in shark fishery. Changes in gear use in Madagascar have been described previously, where gear preference had shifted from gill nets to less selective longlines, with smaller sharks being targeted (McVean *et al.* 2006; Short, 2011). Randriamiarisoa (2008) also noted a decrease in the size of sharks landed in the traditional fishery in Madagascar, and that with fishers reporting decreasing catches, production was maintained through greater effort; and Robinson and Sauer (2013) reported decreases in abundance and size of sharks in the northern artisanal fishery.

Artisanal shark fisheries in other countries have shown similar responses to declines in shark landings; in South Africa previously discarded catches have been targeted (Kroese *et al.* 1996); and in the Maldives, markets developed for smaller sharks (Anderson & Waheed, 1999). In Indonesia catch and fishing effort for elasmobranchs has increased whilst catch per unit effort and average size of sharks has decreased (Keong, 1996; White & Cavanagh, 2007).

The size of sharks recorded here, with the majority of hammerheads estimated to be immature, is also of concern. The median size range in this study (51-60 cm) is already less than the 1 m standard length reported in McVean *et al.* (2006). Large numbers of juvenile and sexually immature sharks have been shown to occur within both artisanal and industrial fisheries (Doherty *et al.* 2014; Bizzarro *et al.* 2009; Dapp *et al.* 2013), as declines in upper tropic level species has increased reliance on smaller, coastal elasmobranchs (Sala *et al.* 2004; Bizarro *et al.* 2009).

Long-term fishing pressure can remove the largest individuals from shark populations (Friedlander & DeMartini, 2002; Sala *et al.* 2014; Doherty *et al.* 2014). The effects of elasmobranch fisheries shifting from targeting upper, trophic level species towards smaller, nearshore species has serious consequences for trophic relationships and knock on effects for ecosystems, such as mesopredator release (Myers *et al.* 2007; Stevens *et al.* 2000; Ferretti *et al.* 2010). The targeting of immature sharks, gravid females and early life stages additionally reduces the productivity and resilience of remaining populations and reduces the likelihood of population recovery (Musick, 1999; Smith *et al.* 2008).

A high proportion of gravid females, neonates and small juveniles could also suggest that shark nursery areas are under heavy fishing pressure (Castillo-Geniz *et al.* 1998; Cartamil *et al.* 2011; Bustamante & Bennett, 2013). It should be noted that some villages in the Belo-sur-Mer region report landing numerous small hammerhead sharks around February each year, and it is assumed that it is likely to be situated close to a nursery ground. It is not known whether nursery areas are found within the coastal areas throughout the rest of the study region but numerous anecdotal reports on decreases in shark sizes and numbers in living memory would suggest that the small size of sharks is a factor of overfishing.

Conservative regional estimates, to account for the fact that villages more dependent on shark fishing were targeted, would be 39 to 65,000 sharks landed.year^{-1} in the traditional fishery in the Toliara province. However, it is likely that the estimate of 65 to 104,000 sharks landed.year^{-1} is more realistic due to the large proportion of data that were not captured by data collectors.

National landings estimates based on dried shark fin weights collected within this study are likely to be underestimated, as the weight of sharks represented by the weight of shark fins, and number of estimated sharks does not correlate. This could be due to the fact that the number of shark fins was not recorded accurately by fin collectors, which given the large number of small fins known to be collected is a possibility (F. Humber, pers. obvs). Additionally, the estimate of four fins per shark could be conservative as up to 6 fins per shark can be taken (Biery & Pauly, 2012). Therefore, we would assume that the national landings estimates are closer to 78 to 471,851 sharks.year^{-1}, with wide annual ranges due to large annual fluctuations in exports and imports reported, and the different assumptions of wet weights used for calculations. Limited data exists on the ratio of dry fin weights to wet weight of shark, although the figure used here of 1.44% is likely to be conservative (Clarke *et al*., 2004). Conversion factors for wet weight of sharks fin to wet weight of whole sharks have also been shown to vary considerably across species and location (Biery & Pauly, 2012), and it we could assume the same is likely for dry shark fin to wet weight of whole sharks.

Randriamiarisoa (2008) estimated annual shark landings of 65,000 to 1,225,000 based on dried shark fin exports from 1995 to 2001. However, the estimated number of sharks taken within the Toliara province alone by the traditional fishers in this study could equal current estimates of the number of sharks represented in Madagascar's official export figures. Although southwest Madagascar has the largest fishing population in Madagascar, sharks are also landed in large numbers in the traditional and artisanal fisheries in the western, northern and eastern regions of Madagascar (Robinson & Sauer, 2013; Doukakis *et al.* 2007; Randriamiarisoa, 2008). Official export figures are considered unreliable and incomplete and there are regular inconsistencies between regional and national data (Randriamiarisoa, 2008; Robinson & Sauer, 2013). Furthermore, although it is estimated that >90% of Madagascar's shark fin exports were to Hong Kong, discrepancies between Madagascar's export figures show that it is likely that other countries are significant importers (Cripps *et al*. 2015). These missing data are not captured within estimates in this study.

High numbers of sharks are also landed as direct catch by national and international industrial boats fishing in Madagascar's waters (Randriamiarisoa, 2008; Le Manach *et al.* 2012; Cripps *et al.* 2015). Industrial bycatch of sharks has also been reported in the Malagasy longline fleet (Rahombanjanahary, 2012). Madagascar has also signed fishing access agreements with at least 10 fishing partners since 1986 (eg.

countries, groups of countries such as the EU, private companies) with an estimated >100 foreign vessels allowed to operate in Madagascar's EEZ (M. Andriamahefazafy unpublished data; Le Manach *et al.* 2012; Cripps *et al.* 2015). Furthermore, reported landings demonstrate some foreign vessels are clearly targeting sharks in Madagascar's waters, with Spanish longliner vessels landing 152 MT of sharks compared to 13.98 MT of tuna in 2011 (European Commission, 2013). It is unlikely that only a small volume of sharks landed outside of the traditional and artisanal fisheries are recorded in Madagascar's national exports as the majority of them will not return to port (G. Cripps pers. comm.).

A number of studies now indicate that both Madagascar's official FAO data and shark export figures could significantly underestimate the total sharks landed in its EEZ (Le Manach *et al.* 2012, Cripps *et al.* 2015, A. Lindhop pers. comm.). Le Manach *et al.* (2012) demonstrated that total fisheries catches are likely to be underreported by at least 40% as well as the significance of small-scale fisheries components within domestic catch (72% in the 2000s). Studies have also highlighted both irregularities between regional and national shark export data, and shark import data (Randriamiarisoa, 2008; Cripps *et al.* 2015).

Underreporting within fisheries is a global problem (Zeller *et al.* 2011a, 2011b; Pauly & Froese, 2012), and in particular within both small-scale fisheries (Jacquet *et al.* 2010; Wielgus *et al.* 2010) and shark fisheries (Worm *et al.* 2013). However, the lack of available data does not just reside on the level of exploitation. The majority of shark fisheries have limited data available on species occurrence and their life history (Bizzarro *et al.* 2007; Motta *et al.* 2005; White & Cavanagh, 2007; Moore, 2012; Moore *et al.* 2012), further hampering effective management (Camhi *et al.* 1998).

The traditional and artisanal shark fisheries in Madagascar increased in financial importance since they were heavily promoted in the 1990s through the handing out of new fishing gears (Cooke, 1997; Du Feu, 1998). The shark fishery has been a major driver of fisher migrations along the western coast of Madagascar (Cripps, 2009) and top quality shark fins can still fetch some of the highest prices per kg of any marine resource in Madagascar, despite recent fluctuations in price (Cripps *et al.* 2015).

The importance of shark fisheries to the present day economy of local fishing communities in Madagascar remains unclear. Barnes-Mauthe *et al.* 2013 found that fishers in southwest Madagascar (study region 1) only occasionally or opportunistically targeted sharks and therefore ranked 15th out of 17 species groups for total market value. Less than five years prior to this study Ravelosoa (2005) found that 70% of fishers from the southwest's regional capital, Toliara, said shark fishing was their primary activity. Anecdotal reports from artisanal fishers in northern Madagascar show that investment in equipment (eg. boats, motors, nets) leave fishers in a cycle to continue to fish sharks despite decreasing catches (Jones, 2014; Cripps *et al.* 2015).

Despite market fluctuations in Madagascar, the price of shark fins clearly increases significantly through the value chain from fisher to exporter, and the main beneficiaries are likely to be the shark fin agents and patrons (owners of artisanal vessels) (Cripps *et al.* 2015). Even governments may see relatively small financial benefits from shark fisheries (Swamy, 1999; Cripps *et al.* 2015).

Community-based monitoring or participatory research has been successfully used not only to assess remote, small-scale fisheries (Uychiaoco *et al.* 2005; Benbow *et al.* 2014) but also illegal fisheries and endangered marine populations (Humber *et al.* 2011; Pilcher & Chaloupka, 2013). Community-based monitoring can also play an important role in engaging stakeholders, building community capacity, and buy in for local management regimes or conservation initiatives (Andrianandrasana *et al.* 2005; Evely *et al.* 2011; Garnier *et al.* 2012).

However community-based methods, despite being cost effective (Humber *et al.* 2011; Holck, 2008), can have their limitations and setbacks. In this study the small monetary incentives lead to falsified data in some cases, but were spotted through the use of digital cameras. Strict data removal policies were applied in this study where any duplication of individuals as multiple sharks was found, as the real data could not be separated from falsified data. Methods to improve monitoring, such as including time stamps on photographs, were trialled but were not feasible due to the fact that batteries were regularly removed from the cameras, to preserve battery life in villages with no access to electricity or new batteries. A trial project using smartphones to monitor the shark fishery in Madagascar is now underway that will not only allow for automatic time and date stamping but increase the speed at which data are available (Blue Ventures Conservation, 2015).

Cameras also provided the means to help identify some shark species landed, although the quality of photos did not always allow for this; and the diverse local nomenclature for shark species meant that it was impossible to draw up a comprehensive list before or during this study. Many photos of sharks were also identified as members of deep-water shark families by experts, for which established taxonomies and IDs are not yet available (David Ebert pers. comm.).

The need for urgent management measures for sharks, in particular for data poor artisanal fisheries, has been increasingly recognised (FAO, 1999; John & Varghese, 2009; Hoq *et al.* 2011). Anti-finning legislation across other countries is not thought to have led to a decrease in global shark mortality and 48% of exploited shark populations are fished above their rebound rate (Worm *et al.* 2013). Although it should be noted that recent trends in changes in attitude to shark fin consumption may have started to reduce market demand (Kao, 2014; Whitcraft, 2014).

Madagascar has neither domestic legislation nor a national plan of action for sharks in place at present (Humber *et al.* 2015). The lack of national legislation is one of the drivers that has led to the decrease in coastal shark populations. In addition, foreign fishing vessels in Madagascar's waters only have licenses with variable bycatch stipulations that have few details on quotas, species limits or monitoring (Euopean Union, 2012; M. Andriamahefazay unpublished data).

In recent years there has been surge of countries taking the lead to implement new management initiatives for sharks (Vince, 2009; Pew Charitable Trusts, 2014), with country-wide and large-scale shark sanctuaries now in place in many countries including the Cook Islands, French Polynesia, Honduras, Maldives, Palau, with commercial fishing also banned in the Bahamas and British Virgin Islands (CMS Sharks MoU, 2015). However, as of late 2014, Madagascar's first shark sanctuary was put in place in Antongil Bay, NE Madagascar, as part of a network of community-managed areas granting local rights for fishery areas (Wildlife Conservation Society, 2015). Shark fishing is now prohibited in the bay through a management plan officially adopted by the *Ministère des Ressources Halieutiques et de la Pêche* (Ministry of Fisheries) (Repoblikan'i Madagasikara, 2014).

It will be important for any shark fisheries management to take into account that >50% of sharks (in tonnes) taken from Madagascar's water could be from foreign fishing vessels either as bycatch or as direct take (Le Manach *et al.* 2012). Efforts by Madagascar to improve fishing access agreements should not only take into account unfair payments, but also the fact that vital marine resources, such as sharks, are being overexploited without record or accountability. The proliferation of bottom-up marine resource management in Madagascar (Rocliffe *et al.* 2014), and the recent shark sanctuary put in place in NE Madagascar, could provide a template for the growth of shark fisheries management in Madagascar through the established network of >64 locally managed marine areas covering >11,000 km^2 (MIHARI, 2015).

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References

Alfaro Shigueto, J., Mangel, J., Pajuelo, M., Dutton, P. H., Seminoff, J. A. & Godley, B. (2010) Where small can have a large impact: Structure and characterization of small-scale fisheries in Peru. Fisheries Research, 106, 8-17.

Anderson, R. C. & Waheed, Z. (1999) In *Case studies of the management of elasmobranch fisheries. FAO Fisheries Technical Paper. No. 378, part 1* (ed R. Shotton), pp. 1- 479. FAO, Rome.

Andrianandrasana, H. T., Randriamahefasoa, J., Durbin, J., Lewis, R. E. & Ratsimbazafy, J. H. (2005) Participatory ecological monitoring of the Alaotra wetlands in Madagascar. *Biodiversity and Conservation,* 14, 2757–2774.

Barnes-Mauthe, M., Oleson, K. L. L. & Zafindrasilivonona, B. (2013) The total economic value of small-scale fisheries with a characterization of post-landing trends: An application in Madagascar with global relevance. Fisheries Research, 147, 175-185.

Baum, J.K., Myers, R.A., Kehler, D.G., Worm, B., Harley, S.J. & Doherty, P.A. (2003) Collapse and Conservation of Shark Populations in the Northwest Atlantic. Science, 299, 389-392.

Baum, J.K. & Myers, R.A. (2004) Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Ecology Letters, 7, 135–145.

Benbow, S., Humber, F., Oliver, T. A., Oleson, K. L. L., Raberinary, D., Nadon, M. & Harris, A. (2014) Lessons learnt from experimental temporary octopus fishing closures in south-west Madagascar: benefits of concurrent closures. *African Journal of Marine Science,* 36, 31-37.

Béné, C. (2006) Small-scale fisheries: assessing their contribution to rural livelihoods in developing countries. FAO Fisheries Circular. No. 1008. pp. 46. FAO, Rome.

Béné, C., Macfadyen, G. & Allison, E. H. (2007) Increasing the contribution of small-scale fisheries to poverty alleviation and food security. FAO Fisheries Technical Paper. No. 481 pp. 125. FAO, Rome.

Biery, L., Palomares, M., Morissette, L., Cheung, W., Harper, S., Jacquet, J., Zeller, D. & Pauly, D. (2011) Sharks in the seas around us: How the Sea Around Us Project is working to shape our collective understanding of global shark fisheries. A report prepared for the Pew Environment Group by the Sea Around Us Project. Fisheries Centre, The University of British Columbia, Vancouver.

Biery, L. & Pauly, D. (2012) A global review of species-specific shark-fin-to-body-mass ratios and relevant legislation. Journal of Fish Biology, 80, 1643-1677.

Bizzarro, J. J., Smith, W. D., Marquez-Farias, J. F. & Hueter, R. E. (2007) Artisanal fisheries and reproductive biology of the golden cownose ray, *Rhinoptera steindachneri* Evermann and Jenkins, 1891, in the northern Mexican Pacific. *Fisheries Research,* 84, 137-146.

Bizzarro, J. J., Smith, W. D., Márquez-Faríasc, J. F., Tyminski, J. & Hueter, R. E. (2009) Temporal variation in the artisanal elasmobranch fishery of Sonora, Mexico. *Fisheries Research,* 97, 103-117.

Blaber, S. J. M., Dichmont, C. M., White, W., Buckworth, R., Sadiyah, L., Iskandar, B., Nurhakim, S., Pillans, R., Andamari, R., Dharmadi & Fahmi (2009) Elasmobranchs in southern Indonesian fisheries: the fisheries, the status of the stocks and management options. Reviews in Fish Biology and Fisheries, 19, 367–391.

Blue Ventures Conservation (2015) Harnessing mobile phone technology to improve small-scale fisheries management. Blue Ventures Conservation, London. Available from: http://blueventures.org/publication/mobile-data-collection-factsheet/

Bustamante, C. & Bennett, M. B. (2013) Insights into the reproductive biology and fisheries of two commercially exploited species, shortfin mako (*Isurus oxyrinchus*) and blue shark (*Prionace glauca*), in the south-east Pacific Ocean. *Fisheries Research,* 143, 174-183.

Camhi, M., Fowler, S., Musick, J., Bräutigam, A. & Fordham, S. (1998) Sharks and their Relatives: Ecology and Conservation. In. IUCN/SSC Shark Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. iv + 39 pp.

Cartamil, D., Santana-Morales, D., Escobedo-Olvera, M., Kacev, D., Castillo-Geniz, L., Graham, J. B., Rubin, R. D. & Sosa-Nishizaki, O. (2011) The artisanal elasmobranch fishery of the Pacific coast of Baja California, Mexico. Fisheries Research, 108, 393-403.

Castillo-Géniz, J. L., Márquez-Farias, J. F., Rodriguez de la Cruz, M. C., Cortés, E. & Cid del Prado, A. (1998) The Mexican artisanal shark fishery in the Gulf of Mexico: towards a regulated fishery. Marine and Freshwater Research, 49, 611–620.

Clarke, S. C., McAllister, M. K. & Michielsens, C. G. J. (2004) Estimates of Shark Species Composition and Numbers Associated with the Shark Fin Trade Based on Hong Kong Auction Data. Journal of Northwest Atlantic Fishery Science, 35, 453-465.

Clarke, S., McAllister, M.K., Milner-Gulland, E.J., Kirkwood, G.P., Michielsens, C.G.J., Agnew, D.J., Pikitch, E.K., Nakano, H. & Shivji, M.S. (2006) Global estimates of shark catches using trade records from commercial markets. Ecology Letters, 9, 1115–1126.

CMS Sharks MoU (2014) Shark Sanctuaries. Memorandum of Understanding on the Conservation of Migratory Sharks. Available from: http://sharksmou.org/shark-sanctuaries

Cooke, A. (1997) Survey of Elasmobranch fisheries and trade in Madagascar. The trade in shark and shark products in the Western Indian and Southeast Atlantic

Oceans (ed. by N.T. Marshall and R. Barnett), pp. 101-130. Traffic East/Southern Africa, Nairobi.

Compagno, L. J. V. (1984) FAO Species Catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2 - Carcharhiniformes. FAO Fish. Synop. 125(4/2): 251-655. FAO, Rome.

Cortés, E., Brooks, E., Apostolaki, P. & Brown, C. A. (2006) National Marine Fisheries Service, Southeast Fisheries Science Center, Panama City, Florida.

Cripps, G., Harris, A., Humber, F., Harding, S. & Thomas, B. (2015) A Preliminary Value Chain Analysis of Shark Fisheries in Madagascar. Report SF/2015/3. Indian Ocean Commission, Ebene, Mauritius.

Dapp, D., Arauz, R., Spotila, J. R. & O'Connor, M. P. (2013) Impact of Costa Rican longline fishery on its bycatch of sharks, stingrays, bony fish and olive ridley turtles (*Lepidochelys olivacea*). *Journal of Experimental Marine Biology and Ecology,* 448, 228-239.

Doherty, P. D., Alfaro-Shigueto, J., Mangel, J., Witt, M. & Godley, B. (2014) Big catch, little sharks: Insight into Peruvian small-scale longline fisheries. *Ecology and Evolution*.

Doukakis, P., Jonahson, M., Ramahery, V., Dieu Randriamanantsoa, B.J.d. & Harding, S. (2007) Traditional Fisheries of Antongil Bay, Madagascar. Western Indian Ocean Journal of Marine Science, 6, 175-181.

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., Carlson, J. K., Davidson, L. N. K., Fordham, S., Francis, M. P., Pollock, C. M., Simpfendorfer, C. A., Burgess, G. H., Carpenter, K. E., Compagno, L. J. V., Ebert, D. A., Gibson, C., Heupel, M. R., Livingstone, S. R., Sanciangco, J. C., Stevens, J. D., Valenti, S. & White, W. T. (2014) Extinction risk and conservation of the world’s sharks and rays. eLife, 3:e00590, 1-34.

Ehrhardt, N. M. & Deleveaux, V. K. W. (2007) The Bahamas’ Nassau grouper (Epinephelus striatus) fishery – two assessment methods applied to a data – deficient coastal population. Fisheries Research, 87, 17-27.

European Union (2012) Fisheries Partnership Agreement between the European Union and the Republic of Madagascar, Council Decision 2012/826/EU (OJ EU L361 of 31.12.2012). European Commission. Available from: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2012.361.01.0011.01.ENG

European Commission (2013). Request for information on long-line catches in West Indian Ocean. D. Standing. Brussels.

Evely, A., Pinard, M., Reed, M. S. & Fazey, I. (2011) High levels of participation in conservation projects enhance learning. Conservation Letters, 4, 116-126.

Food and Agriculture Organisation (FAO) (1999) International Plan of Action for the Conservation and Management of Sharks (IPOA). FAO, Rome.

FAO (2013) FishStatJ - software for fishery statistical time series. Food and Agriculture Organization of the United Nations.

Ferretti, F., Myers, R.A., Serena, F. & Lotze, H.K. (2008) Loss of Large Predatory Sharks from the Mediterranean Sea. Conservation Biology, 22, 952–964.

Ferretti, F., Worm, B., Britten, G. L., Heithaus, M. R. & Lotze, H. K. (2010) Patterns and ecosystem consequences of shark declines in the ocean. Ecology Letters, 13, 1055-1071.

du Feu, T. A. (1998) Fisheries Statistics for the Large Meshed Gill Net Fishery, North West Madagascar. pp. 75. Promotion de la Peche Maritime Tradtionnelle et Artisanale, Helle Ville, Madagascar.

Field, I.C., Meekan, M.G., Buckworth, R.C. & Bradshaw, C.J.A. (2009) Susceptibility of Sharks, Rays and Chimaeras to Global Extinction. Advances in Marine Biology, 56, 275 - 363.

FishBase (2015) FishBase.org. Accessed 17th October 2014.

Fourmanoir, P. (1961) Requins de la côte ouest de Madagascar. Mémoires de l'Institut Scientifique de Madagascar, Série F. Océanographie, Tome IV, 3-81.

Friedlander, A. M. & DeMartini, E. E. (2002) Contrasts in density, size, and biomass of reef fishes between the northwestern and the main Hawaiian islands: the effects of fishing down apex predators. *Marine Ecology Progress Series,* 230, 253-264.

Garnier, J., Hill, N., Guissamulo, A., Silva, I., Witt, M. & Godley, B. (2012) Status and community-based conservation of marine turtles in the northern Querimbas Islands (Mozambique). *Oryx,* 46, 359-367.

Hayes, C., Jiao, Y. & Cortés, E. (2009) Stock assessment of Scalloped Hammerheads in the Western North Atlatic Ocean and Gulf of Mexico. North American Journal of Fisheries Management, 29, 1406-1417.

Holck, M. H. (2008) Participatory forest monitoring: an assessment of the accuracy of simple cost–effective methods. *Biodiversity and Conservation,* 17, 2023–2036.

Hoq, M. E. (2011) Sharks - a threatened biodiversity in the coastal water of Bangladesh. In *Shark fisheries in the Bay of Bengal, Bangladesh: Status and potentialities. Support to Sustainable Management of the BOBLME Project* (eds M. E. Hoq, A. K. Yousuf Haroon & M. G. Hussain), pp. 61-68. Bangladesh Fisheries Research Institute, Bangladesh.

Humber, F., Godley, B. J., Ramahery, V. & Broderick, A. C. (2011) Using community members to assess artisanal fisheries: the marine turtle fishery in Madagascar. Animal Conservation, 14, 175–185.

Humber, F., Andriamahefazafy, M., Godley, B. & Broderick, A. (2015) Endangered, essential and exploited: how extant laws are not enough to protect marine megafauna in Madagascar. Marine Policy, 60,70-83.

IUCN (2015). IUCN Red List of Threatened Animals, IUCN, Gland and Cambridge.

Jacquet, J., Fox, H., Motta, H., Ngusaru, A. & Zeller, D. (2010) Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. African Journal of Marine Science, 32, 97-106.

John, M. E. & Varghese, B. C. (2009) Decline in CPUE of Oceanic Sharks in the Indian EEZ : Urgent Need for Precautionary Approach. IOTC Working Party on Ecosystems and Bycatch. IOTC-2009-WPEB-17. IOTC, Mombasa.

Jones, B. (2014) Shark Fishers in Madagascar Sell Fins for Pennies. National Geographic. http://voices.nationalgeographic.com/2014/02/13/shark-fishers-in-madagascar-sell-fins-for-pennies/

Kao, E. (2014) Shark fin trade from Hong Kong to China drops almost 90 per cent in one year. South China Morning Post. Accessed 19th May 2015.

Keong, C. H. (1996) Shark fisheries and the trade in sharks and shark products of southeast Asia. pp. 129. Traffic Southeast Asia, Petaling Jaya.

Kroese, M., Sauer, W. H. & Penney, A. J. (1996) An overview of shark catches and by-catches in South African fisheries. Collective Volume of Scientific Papers ICCAT, 45, 318-328.

Kroese, M. & Sauer, W. H. H. (1998) Elasmobranch exploitation in Africa. Marine and Freshwater Research, 49, 573 - 577.

Laroche, J. & Ramananarivo, N. (1995) A preliminary survey of the artisanal fishery on coral reefs of the Tulear region (southwest Madagascar). Coral Reefs, 14, 193-200.

Le Manach, F., Gough, C., Humber, F., Harper, S. & Zeller, D. (2011). Reconstruction of total marine fisheries catches for Madagascar (1950-2008). pp. 21-37. In: Harper, S. and Zeller, D. (eds.) Fisheries catch reconstructions: Islands, Part II. Fisheries Centre Research Reports 19(4). Fisheries Centre, University of British Columbia [ISSN1198-6727].

Le Manach, F., Gough, C., Harris, A., Humber, F., Harper, S. & Zeller, D. (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy, 36, 218-225.

McVean, A., Walker, R. & Fanning, E. (2006) The traditional shark fisheries of southwest Madagascar: A study in the Toliara region. Fisheries Research, 82, 280-289.

MIHARI (2015). MIAHRI – Madagascar's locally managed marine area network. Available from: http://blueventures.org/publication/mihari-madagascars-locally-managed-marine-area-network/

Moore, A. B. M. (2012) Elasmobranchs of the Persian (Arabian) Gulf: ecology, human aspects and research priorities for their improved management. Reviews in Fish Biology and Fisheries, 22, 35-61.

Moore, A. B. M., Ward, R. D. & Peirce, R. (2012) Sharks of the Persian (Arabian) Gulf: a first annotated checklist (Chondrichthyes: Elasmobranchii). Zootaxa, 3167, 1-16.

Motta, F. S., Gadig, O. B. F., Namora, R. C. & Braga, F. M. S. (2005) Size and sex compositions, length–weight relationship, and occurrence of the Brazilian sharpnose shark, Rhizoprionodon lalandii, caught by artisanal fishery from southeastern Brazil. Fisheries Research, 74, 116–126.

Musick, J. (1999) Criteria to Define Extinction Risk in Marine Fishes: The American Fisheries Society Initiative. *Fisheries,* 24, 6-14.

Myers, R. A., Baum, J. K., Shepherd, T., D., Powers, S. P. & Peterson, C. H. (2007) Cascading Effects of the Loss of Apex Predatory Sharks from a Coastal Ocean. *Science,* 315, 1846-1850.

Pascal, B. (2003) Requin et tortues de mer chez les Vezo du Sud-Ouest de Madagascar. Enjeux écologiques ou enjeux sociaux? Mémoire de DEA, Université d'Orléans, Orléans.

Pauly, D. & Froese, R. (2012) Comments on FAO's State of Fisheries and Aquaculture, or 'SOFIA 2010'. *Marine Policy,* 36, 746–752.

Pew Charitable Trusts (2014) Chuuk State Enacts Bill to Protect Sharks. Pew Charitable Trusts.

Pilcher, N. J. & Chaloupka, M. (2013) Using community-based monitoring to estimate demographic parameters for a remote nesting population of the Critically Endangered leatherback turtle. *Endangered Species Research,* 20, 49-57.

R Development Core Team (2010). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Rahombanjanahary, D. M. (2012) Catch rates of sharks as bycatch by Malagasy longliners. 08th Working Party on Ecosystem and Bycatch. pp. 11. Direction

Generale de la Peche et des Ressources Halieutiques. Unité Statistique Thonière d’Antsiranana, Antsiranana.

Randriamiarisoa (2008) Biologie et ecologie des especes exploitees et caracteristiques de la pecherie tradtionnelle aux requins sur les cotes ouest et nord-ouest de Madagascar. These de doctorat en sciences agronomiques, Universite d'Antananarivo. Ecole superieure des sciences agronomiques.

Ravelosoa, J. (2005) In Projet de conservation des requins programme Madagascar Wildlife Conservation Society, Ministère de l'Agriculture et de l'Elevage et de la Pêche de Madagascar, Antananarivo.

Repoblikan’i Madagasikara (2014). Arrêté Ministeriel No. 37.069/2014 portant définition du plan d’aménagement concerté des pêcheries de la baie d’Antongil [Ministerial Order No. 37.069/2014 relating to the definition of a collaborative fisheries management plan for Antongil Bay] Antananarivo, Madagascar. 18th December

Robinson, L. & Sauer, W.H.H. (2013) A first description of the artisanal shark fishery in northern Madagascar: implications for management. African Journal of Marine Science, 35, 9 – 15.

Rocliffe, S., Peabody, S., Samoilys, M. & Hawkins, J. P. (2014) Towards A Network of Locally Managed Marine Areas (LMMAs) in the Western Indian Ocean. PLoS ONE, 9, 1-14.

Sala, E., Aburto-Oropeza, O., Rez, M., Paredes, G. & López-Lemus, L. G. (2004) Fishing down coastal food webs in the Gulf of California. *Fisheries,* 29, 19–25.

Salas, S., Chuenpagdee, R., Seijo, J. C. & Charles, A. (2007) Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. Fisheries Research, 87, 5–16.

Shehe, M. A. and Jiddawi, N. S. (2002). The status of shark fisheries in Zanzibar. Elasmobranch Biodiversity, Conservation and Management. Proceedings of the International Seminar and Workshop, Sabah, Malaysia, July 1997. S. Fowler, T. M. Reed and F. A. Dipper, IUCN SSC Shark Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.

Short, R. E. (2011) Interdit D'Interdire – Identification Of Pitfalls In Development Of Community Management For Shark Fisheries Of Northern Madagascar. Master of Science and Diploma of Imperial College, Imperial College.

Smale, M. J. (1998) Evaluation of shark populations around the Masoala Peninsula, North East Madagascar. Final report. Wildlife Conservation Society, Antananarivo.
Smith, W. D., Cailliet, G. M. & Cortés, E. (2008) Demography and elasticity of the diamond stingray, *Dasyatis dipterura*: parameter uncertainty and resilience to fishing pressure. *Marine and Freshwater Research,* 59, 575–586.

Stevens, J. D., Bonfil, R., Dulvy, N. K. & Walker, P. A. (2000) The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science,* 57, 476–494.

Swamy, K. (1999) In *Case studies of the management of elasmobranch fisheries. FAO Fisheries Technical Paper. No. 378, Part 2* (ed R. Shotton), pp. 480-920. FAO, Rome.

Uychiaoco, A. J., Arceo, H. O., Green, S. J., De La Cruz, M. T., Gaite, P. A. & Alino, P. M. (2005) Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. *Biodiversity and Conservation,* 14, 2775–2794.

Varkey, D.A., Ainsworth, C.H., Pitcher, T.J., Goramb, Y. & Sumaila, R. (2010) Illegal, unreported and unregulated fisheries catch in Raja Ampat Regency, Eastern Indonesia. Marine Policy, 34, 228–236.

Vieira, S. & Tull, M. (2008) Restricting fishing: a socio-economic impact assessment of artisanal shark and ray fishing in Cilacap. Bulletin of Indonesian Economic Studies, 44, 263-287.

Vince, G. (2009) Maldives moves to protect its sharks. BBC News. Accessed 27th August 2014.

Wielgus, J., Zeller, D., Caicedo-Herrera, D. & Sumaila, R. (2010) Estimation of fisheries removals and primary economic impact of the small-scale and industrial marine fisheries in Colombia. Marine Policy, 34, 506-513.

White, W. T. & Cavanagh, R. D. (2007) Whale shark landings in Indonesian artisanal shark and ray fisheries. Fisheries Research, 84, 128-131.

Whitcraft, S., Hofford, A., Hilton, P., O'Malley, M., Jaiteh, V. & Knights, P. (2014) Evidence of declines in shark fin demand, China. pp. 21. WildAid, San Francisco.

Wildlife Conservation Society (2015) Government of Madagascar Creates Country's First Shark Sanctuary. WCS. Available from: http://press.wcs.org/NewsReleases/tabid/13614/articleType/ArticleView/articleId/6563/Government-of-Madagascar-Creates-Countrys-First-Shark-Sanctuary.aspx. Accessed 17th February 2015.

World Bank/FAO/WorldFish Center (2010) The hidden harvests: the global contribution of capture fisheries. Conference Edition. Agriculture and Rural Development Department and Sustainable Development Network, Washington DC.

Worm, B., Davis, B., Kettemer, L., Ward-Paige, C.A., Chapman, D., Heithaus, M.R., Kessel, S.T. & Gruber, S.H. (2013) Global catches, exploitation rates,and rebuilding options for sharks. Marine Policy, 40, 194-204.

Zeller, D., Booth, S., Pakhomov, E., Swartz, W. & Pauly, D. (2011) Arctic fisheries catches in Russia, USA, and Canada: baselines for neglected ecosystems. *Polar Biology,* 34, 955–973.

Zeller, D., Rossing, P., Harper, S., Persson, L., Booth, S. & Pauly, D. (2011) The Baltic Sea: Estimates of total fisheries removals 1950–2007. *Fisheries Research,* 108, 356-363.

Table 1. Recorded shark landings for each village in the study. The number of months of monitoring per year is included in brackets. Region 1 = Andavadoaka (Figure 1) and Region 2 = Belo-sur-Mer (Figure 1). DR = Data collection occurred but data removed during verification process. Dashes indicate no data collection occurred. Human population data from Oleson *et al.* unpublished data; Jones 2012; ACDEM census; Fokontany 2013; [a]No official survey done, estimation by Blue Ventures; *Monthly census data collected between October 2009 and March 2011 by Blue Ventures.

Region	**Village**	**Human population 2010**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Estimated total landings (2007-12)**
1	Ampasilava	507	7 (12)	20 (12)	44 (12)	30 (12)	21 (12)	127 (12)	249
1	Andavadoaka	1419	573 (12)	326 (12)	592 (9)	DR	DR	DR	2478
1	Andranombala	168	125 (12)	98 (12)	99 (12)	35 (3)	DR	DR	589
1	Ankitambagna	97	30 (12)	49 (12)	0 (3)	1 (4)	22 (11)	27 (10)	140
1	Antsepoke	270[a]	16 (12)	13 (12)	13 (12)	3 (10)	47 (12)	70 (12)	166
1	Belavenoke	489	37 (8)	20 (12)	59 (10)	207 (10)	114 (12)	241 (12)	696
1	Bevato	531	40 (12)	170 (12)	65 (12)	110 (12)	101 (12)	149 (12)	635
1	Lamboara	612	79 (12)	72 (12)	301 (12)	1157 (12)	553 (12)	687 (12)	2849
1	Nosy Lava	350[a]	16 (10)	87 (5)	-	-	-	-	205
1	Nosy Mitata	39	-	-	-	-	-	10 (3)	60
2	Ampatiky	480[a]	-	197 (8)	674 (12)	199 (12)	284 (12)	213 (12)	1621
2	Ankevo	649	-	-	DR	DR	265 (11)	434 (12)	1232
2	Antanagnabo	193	-	-	-	-	-	58 (4)	82
2	Antsaranandaka	100[a]	-	39 (3)	-	-	-	-	129
2	Belagnora	170	-	29 (5)	-	-	-	-	36
2	Belalanda	471	-	126 (8)	-	-	-	-	150
2	Belo-sur-Mer	2594	-	120 (8)	2 (7)	-	-	-	156
2	Betania	1342	-	73 (8)	136 (6)	DR	9 (8)	36 (12)	311

2	Manahy	125	-	-	-	-	-	131 (4)	227
2	Nosy Andravoho	0-100*	-	-	109 (3)	198 (7)	-	-	434
2	Nosy Andriamitaroke	6-449*	-	65 (4)	328 (7)	908 (11)	-	-	1358
2	Nosy Be	15-232*	-	61 (1)	DR	DR	DR	53 (2)	1654
Total			**923**	**1565**	**2422**	**2848**	**1416**	**2254**	**15457**

Figure 1. Map showing the two regions of data collection within in this study. Region 1 surrounds the village of Andavadoaka and Region 2 surrounds the village of Belo-sur-Mer. The two largest towns found in each region (Region 1: Morombe; Region 2: Morondava) are also shown.

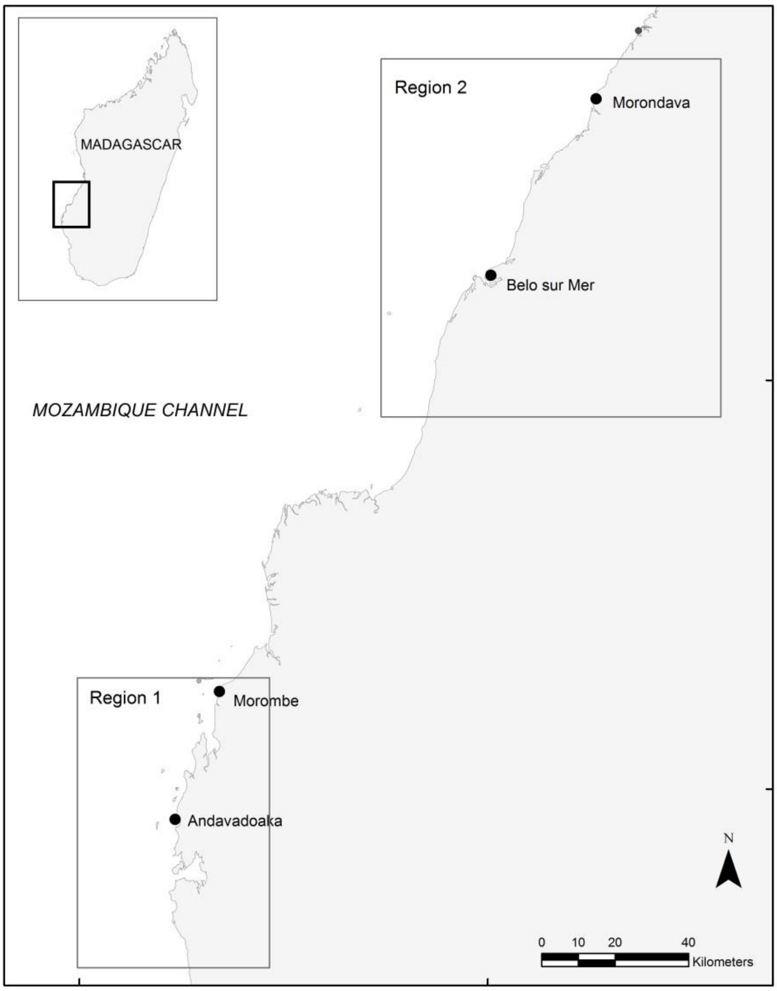

Figure 2: The main shark species by percentage by region. All remaining landed sharks are categorised as “Other” in this figure. No local name within this category accounted for >2% (region 1) or >10% (region 2) of recorded landings.

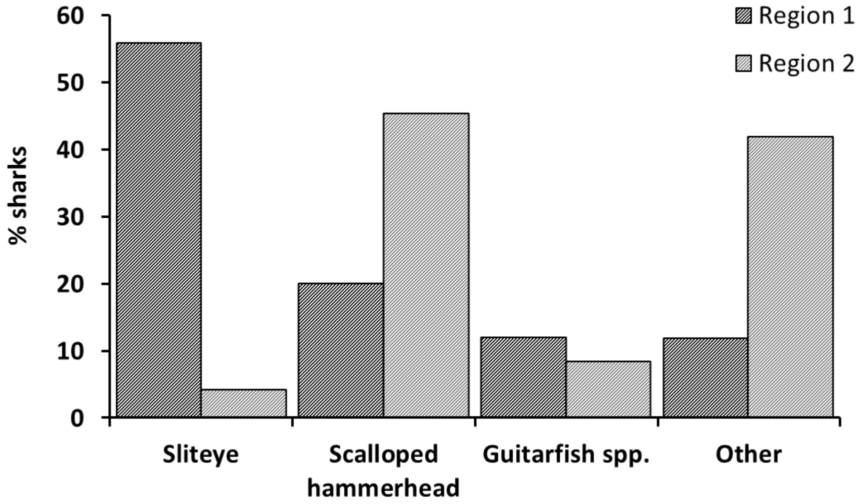

Figure 3. Size frequency of scalloped hammerheads (*S. lewini*), sliteve (*L. macrorhinus*) and guitarfish sp. (Rhinobatidae), recorded 2007-2012 in SW Madagascar. Graphs are shown by sharks recorded as female (a,c,e) and male (b,d,f). Size class is Total length (TL) for graphs a-d. Pre-caudal length (PCL) was converted to estimated Total length (TL) for scalloped hammerheads and sliteye sharks using equations in Table S1. Size class is pre-caudal length for graphs e-f. Graphs a to d: Dotted lines on graphs a to d represent minimum TL at maturity: scalloped hammerheads 212 cm (female) and 140 cm (male); sliteye 79 cm (female) and 62 cm (male) (Compagno 1984).Graphs e to f: Dotted lines indicate minimum PCL (~158 cm) at maturity for *R. djiddensis*. Dashed lines indicate maximum PCL (~125 cm) for *R. annulatus.* Minimum PCL at maturity and maximum PCL were calculated from known length-length equations for *R. djiddensis* (Table S1) (Fishbase.org).

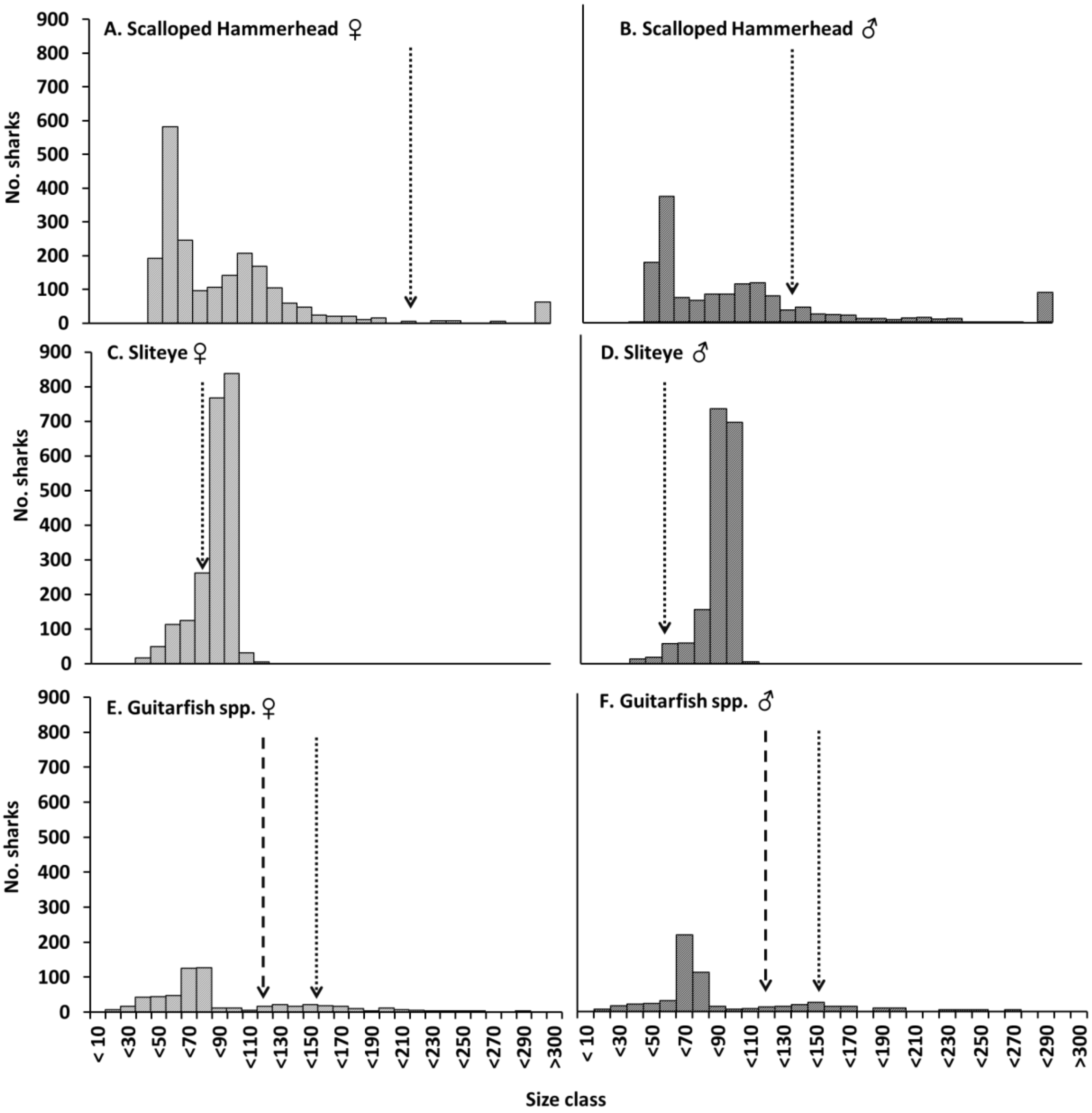
A. Scalloped Hammerhead ♀
B. Scalloped Hammerhead ♂
C. Sliteye ♀
D. Sliteye ♂
E. Guitarfish spp. ♀
F. Guitarfish spp. ♂
No. sharks
0
100
200
300
400
500
600
700
800
900
< 10
<30
<50
<70
<90
<110
<130
<150
<170
<190
<210
<230
<250
<270
<290
>300
Size class

Figure 4. Average shark size (PCL) by species or family over both regions (2007-2012). SD bars are shown for each year. Other contains all sharks recorded that were not classified as one of the three species/family.

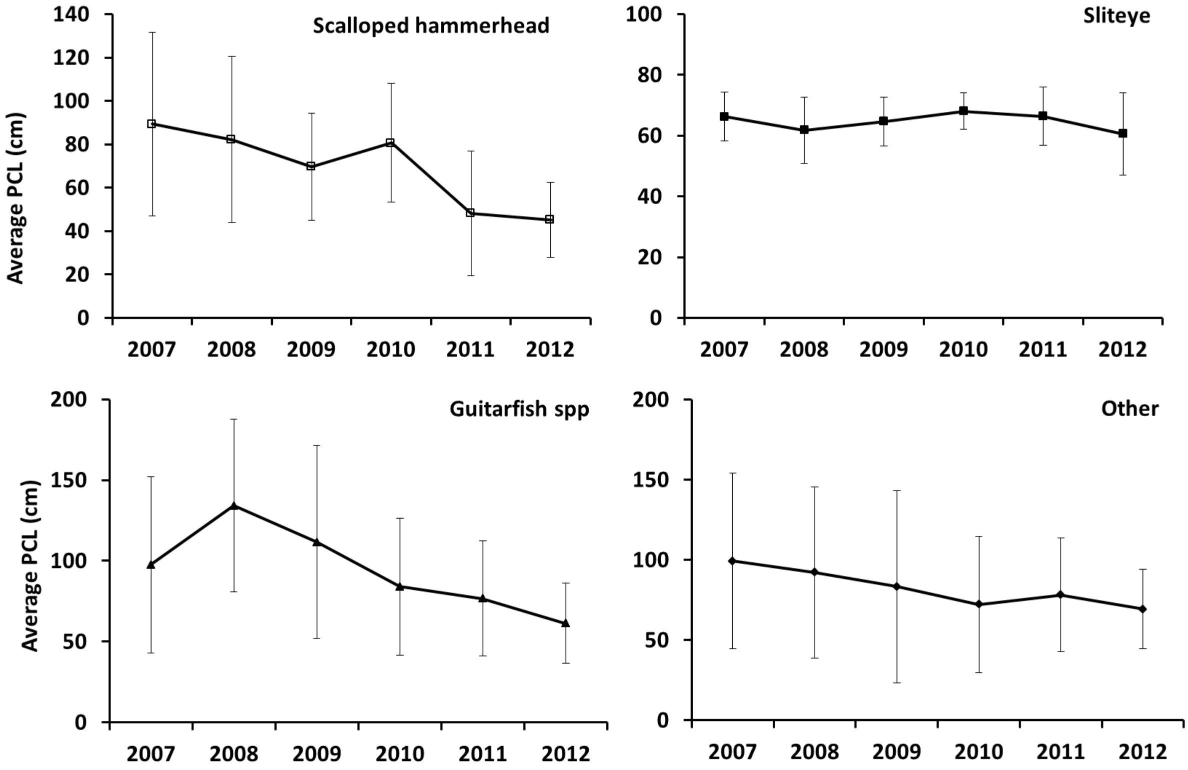

Figure 5. Total (OBS) and estimated (EST) landings recorded in (a) Region 1 villages (Ampasilava, Antsepoke, Belavenoke, Bevato and Lamboara) with at least 8 months monitoring for each year 2007 to 2012 and (b) Region 2 villages (Ampatiky, Ankevo and Betania) that recorded data for a minimum of four years. ND = No data for Region 2 in 2007 as monitoring did not start until May 2008.

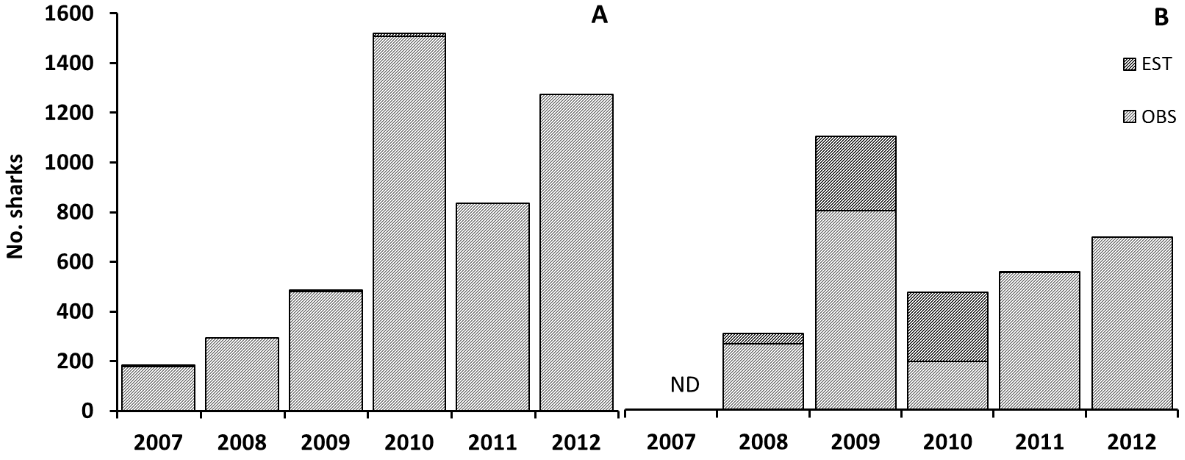

Figure S1. Total landings recorded 2007-2012 and estimated landings in six villages for those villages with long-term datasets. Region 1 villages (Ampasilava, Antsepoke, Belavenoke, Bevato and Lamboara) and region 2 village (Ampatiky) all had a minimum of 8 months monitoring for each year 2007 - 2012. ND = No data for region 2 in 2007 as monitoring did not start until May 2008.

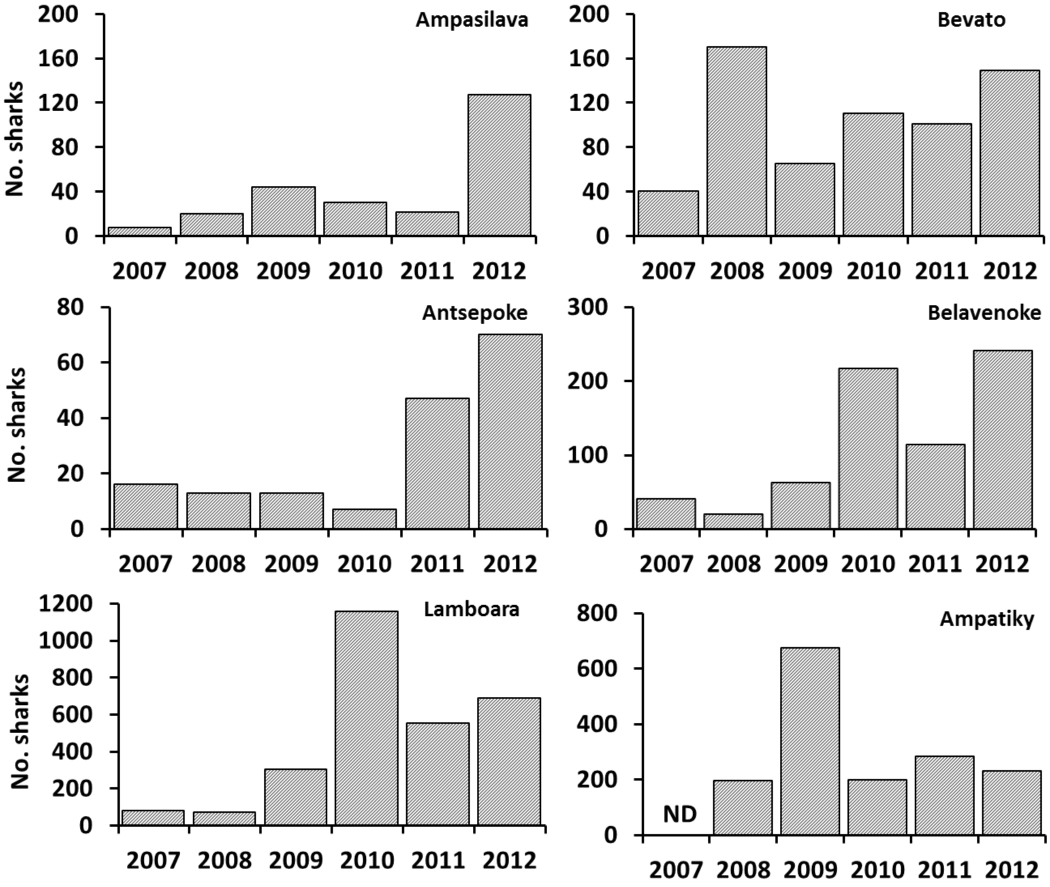

Figure S2. The number of each main species or family 2007-2012 in region 1(a to d) and region 2 (e to h). ND = no data monitoring in region until May 2008.

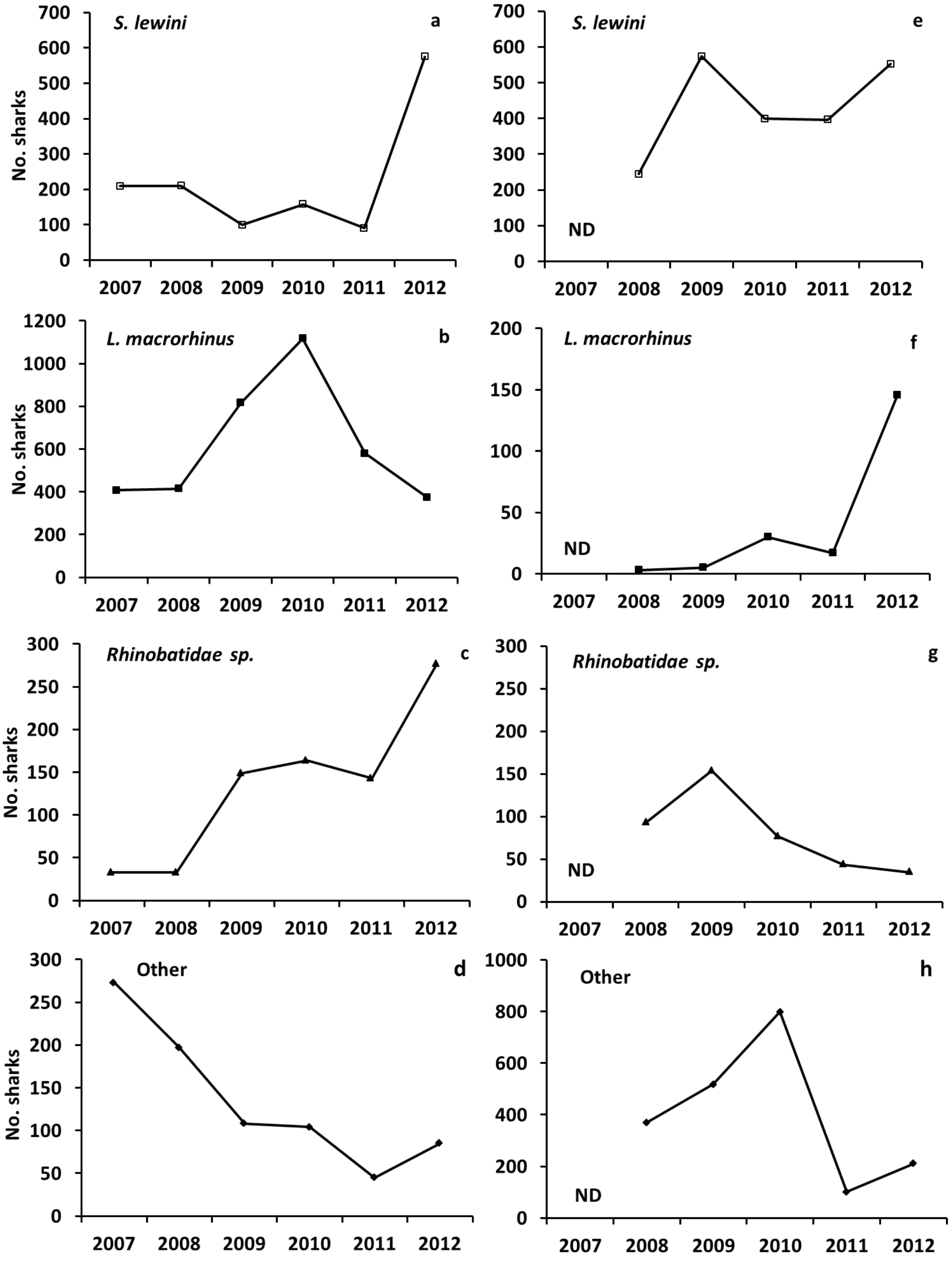

Table S1. Summary landings and length-length conversion formulas for the top three elasmobranch species and/or families landed. SL (Standard length) is equivalent to PCL (pre-caudal length).

Latin name	**Local name**	**% (No.)**	**PCL (cm)**			**Total length at first maturity (cm)**		**Length conversion formula**	**References**
			Min	**Max**	**Mean ± SD**	**Male**	**Female**		
Loxodon macrorhinus	Kasioke, Mangaraoro	34.4 (3930)	18	93	65.3 ± 9.4	62-66	79	TL = 0 + 1.293 x SL	Compagno 1984; Fishbase.org
Sphyrna lewini	Viko, Palaloha	30.7 (3505)	20	270	63.6 ± 32.1	140 - 165	212	Other = 0 + 0.704 x TL	Compagno 1984; Fishbase.org
Rhinobatidae spp. (Four species recorded in literature and Fishbase.org).	Soroboa, Soroboa vato	10.5 (1202)	14	300	89.5 ± 50.6	157-178 (*R. ancylostoma*); 177 (*R. djiddensis*)		SL = 0 + 0.851 x TL (*R. ancylostoma*); TL = 0 + 1.118 x SL (*R. djiddensis*)	Fishbase.org

Table S2: List of local names given to sharks during community-based monitoring of shark fishery 2007-2012. Identification of local names was through previous reports and papers, and from photographs presented to three experts. Asterisks in brackets indicate the confidence in their species identification as *** confident or ** probable. The appearance of two latin names indicates either the ID of two separate photos under the same local name or a + sign for two conflicting identifications. IUCN Red List category provided in square brackets: DD = Data Deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered.

		Identification(s)	**Alternative names given**			
Local name given	**Total number recorded**	**Latin name**	**Other name 1**	**Other name 2**	**Other name 3**	**Other name 4**
Andranomamy	9	_Hemipristis elongata_ (***) [VU]	Ogne			
Balemy	3		Baleme			
Balidake	264	_Centrophorus moluccensis_ (***) [DD]; Mustelus sp.	Gogo			
Balita	1		Balidake	Tsinike		
Bemaso	12		Kary	Taska	Tigre	
Besofy	9		Meso	Dofinkoro		
Bevombotse	10		Vantare	Meso		
Blue	2		Bole			
Bobokoro	1		None given			
Bole	1		Blue			
Boriloha	24		Dofonkoro/Dofinkoro			
Dofikoro	124	_Carcharhinus sorrah_ (***) [NT]	Boriloha	Besofy		
Fatike	396	_C. moluccensis_ (***); Squalus sp.; Mustelus sp.	Gogo	Balidake		
Fesoke	257	_C. sorrah_ (***); _Carcharhinus limbatus_ (**) [NT]	Fesotse			
Fesotse	38	_Carcharhinus amblyrhynchos (***)_ [NT]; Carcharhinus sp.	Fesoke			

Fireke	1		Firekembole			
Firekembole	1		Fireke			
Fotivonto	134	*Carcharhinus brevipinna* [NT] or C. *limbatus* (**)	Foty rambo			
Foty	27		Valovombotse	Foty		
Foty rambo	18		Foy vonto			
Garamaso	23		Tomagny manente	Doany		
Gogo	16		Fatike	Balidake	Tsinike	
Hiahia	18		Hiahia			
Jalinta	4	*Stegostoma fasciatum* [VU]	Jangita	Angriagninta		
Jangita	19	*S. fasciatum*	Jalinta	Angriagninta		
Kary	48	*Galeocerdo cuvier* [NT]	Bemaso	Tsaka	Tigre	
Kasioke	3912	*Loxodon macrorhinus* [LC]	Mangaraoro	Keliterake		
Katsatsake	47		Katsatsake	Tsatsake	Mangaraoro	Keliterake
Keliterake	27		Mangaraoro	Tsatsake		
Lava Loha	2		Maragnitsoro	Lavaoro		
Lavaoro	452	*C. sorrah (***); C. limbatus (***)*	Maragnitsoro	Lava loha		
Lejeleja	3		Tomango	Tandaly		
Maintindambosy	74	*Carcharhinus leucas (**)* [NT]*; C. sorrah (**)*	Maintindambosy			
Maintipaty	158	*C. sorrah* (**)	Maintipaty			
Mangaraoro	18	*L. macrorhinus*	Mangarangaraoro	Kasioke		
Manofaty	1		None given			
Maragnitsoro	280	*C. sorrah* (***); *L. macrorhinus* (***); *H. elongata* (***) ; Hamigaleid sp.	Meso	Maranitsoro	Lavaoro	Lavaloha
Meso	19		Maranitsoro			
Ogne	1		None given			
Palaloha	760	*Sphyrna lewini* [EN]	Viko	Kitsele loha		
Ragnaragna	14		None given			
Ranomaso	5		Tomagnimanete			
Santira	13		Bole			

Soroboa	1200	Guitarfish spp.; + *Rhynchobatus djiddensis* (**) [VU]; *Rhynchobatus laevis* (**) [VU]	None given		
Soroboavato	2	Guitarfish spp.	None given		
Tandaly	28		Tandaly	Tomango	Lejaleja
Tomango	49	*Triaenodon obesus* (***) [NT]	Tandaly	Lejaleja	
Tsaka	1		Tigre	Bemaso	Kary
Tsatsake	57		Mangaraoro	Keliterake	
Vaevae	6	Pristiophoridae [LC to DD]	Vava		
Valovombotse	11		Foty	Valovomboky	
Vantare	3		Bevombotse	Meso	
Vao	19		Dofonkoro	Boriloha	
Vatar	4		Bevombotse	Vantare	
Viko	2745	*S. lewini*	Palaloha	Kitsele loha	
Voro	1		Kary	Tsaka	
Ray Names					
Andema	2				
Fairara	5				
Faitane	1				
Faivalany	1				
Fay	3				
Fay Behohi	2				
Fay Ndoany	2				
Fay Ndramiango	1				
Fay Sify	1				
Fay Tany	4				
Fay Tombily	3				
Fay Vanda	1				
Makoba	4				
Makoba Tombily	1				

No name given	25
Total	11,428

Table S3: Shark species given in other studies in Madagascar, the location of the study, and alternative Malagasy names provided.

Reference abbreviations: 1 Robinson & Sauer 2013; 2 McVean *et al.* 2006; 3 Cooke 1997; 4 Doukakis *et al.* 2011.

NW, SW, SE, W, N, NE, E represent geographical regions. Specific location abbreviations: TOL = Toliara; TOG = Tolagnaro; MOR = Morombe; MOD = Morondava; MAH = Mahajanga; ANT = Antseranana; SAM = Sambava; STM = St. Marie; TOA = Toamasina; MAN = Mankara; NBE = Nosy Be.

			Region													
			NW	**SW**	**SW (TOL)**	**SE (TOG)**	**SW (MOR)**	**W (MOD)**	**NW (NBE)**	**NW (MAH)**	**N (ANT)**	**NW (SAM)**	**NE (STM)**	**E (TOA)**	**E (MAN)**	**NE**
Scientific name	**Common name**	**This study**	**1**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**4**
Alopias superciliosus	Bigeye thresher				Tomanimanente		Tomanimanente	Garamaso					Antsingoraeo	Amboso	Sarsatrana	
Alopias vulipnus	Thresher			Santira									Antsingora firaka	Amboso	Sarsatrana	
Carcharhinus albimarginatus	Silvertip shark		Fotsy halahala	Fotyrambo									Atsantsa "boeing"	Atsantsa "boeing"	Atsantsa "tergal"	Antsingora-biloha
Carcharhinus amblyrhynchos	Grey reef shark		Botra mavo	Tomanimanente												x
Carcharhinus amboinensis	Java shark, pigeye shark		x					Dofokoro	Beloha			x				Antsingora-dofodoha; Antsingora fotsy
Carcharhinus brachyurus	Copper shark		x	Mbato												
Carcharhinus brevipinna	Spinner shark	x	x	Maintepate		x										Antendromaso; Antsingora; Antsingora tapakafo

Carcharhinus falciformis	Silky			Gofo		Ranorano		Lavaoro				Atsantsa	Antsingora andromy	Atsantsa "boeing"	Atsantsa vato	
Carcharhinus leucas	Bull shark	x	Botra mavo	Boriloha												x
Carcharhinus limbatus	Blacktip shark	x	Botra mavo	Maintepate												x
Carcharhinus longimanus	Oceanic White-tip				Meso	Bevombotsy; Belay; Besofy	Meso					x	Antsingoraeo	Atsantsa "boeing"	Atsantsarany	
Carcharhinus melanopterus	Blacktip reef shark		x	Maintepate	Maintepate	Mentitehoky	Maintepate	Maintipaty			Botramavo	Botramavo	Antsingoa fasina	Atsantsa "boeing"	Atsantsamary	
Carcharhinus obscurus	Dusky			Foty												Antsingora fotsy; Antsingora mainty
Carcharhinus plumbeus	Sandbar			Bevombotse												Antsingora fotsy
Carcharhinus sealei	Blacktop															
Carcharhinus sorrah	Spot-tail shark	x	Anja	Maintepate; Meso	Fesoke		Fesoke	Fesotse	x						Atsantsamlahona	Antendro-maso; Antsingora; Antsingora fotsy
Carcharias taurus	Sand tiger shark															
Carcharodon carcharias	Great White			Farao; Masiake												
Centrophorus moluccensis	Smallfin gulper shark	x														
Chilosyllium caerulopunctatum	Bluespotted bambooshark															
Chiloscyllium griseum	Grey Bamboo				Hiahia		Hiahia	Hiahia								
Galeocerdo cuvier	Tiger shark		Requin tigre	Vorotse; Bemaso; Tsaka		Vasian-dahy; Lay vanda					Kary	x	Antsingora ("tigre")	Atsantsa-vandana; Atsantsa-vahona	Atsantsa-vandana	Antsingora bosy
Ginglymostoma brevicaudatum	Short-tail nurse				Voritse		Voritse									
Hemipristis elongata	Snaggletooth shark	x	x													x
Hexanchus	Bluntnose															

griseus	sixgill shark															
Hexanchus nakamurai	Bigeyed Sixgill Shark	x														
Isurus spp.	Mako			Jinganify; Mintseka; Sabonto												
Isurus oxyorinchus	Shortfin mako	x			Bevombotse		Bevombotse									
Isurus alatus	Longfin mako															
Loxodon macrorhinus	Sliteye shark	x	Lavahejaka (Ramena); Mandry anala (Ampasindava)						x							Antsingora; Antsingora fotsy; Antsingora lava tsiko
Mustelus sp.	Smooth hounds	x														x
Nebrius ferrugineus	Tawny nurse shark		Ambontso		Valovom--botse			Valovombotse						Amboso	Valorirana; Satrana	
Negaprion acutidens	Sharptooth lemon shark		x									x				
Odontaspis ferox	Small-tooth Sand Tiger				Foty		Foty	Foty		x						
Odontaspis noronhai	Bigeye Sand Tiger															
Prionace glauca	Blue	x											Antsingora firaka			Antendromaso
Pristiophoridae	Sawshark	x														
Pristiophorus nancyae	African dwarf sawshark	x														
Pseudoginglymostoma brevicaudatum	Shorttail nurse shark	x														
Rhina ancylostoma	Bowmouth guitarfish		Tandraly													
Rhiniodon typus	Whale				Trozo	Ingahibe		Kary								
Rhizoprionodon acutus	Milk shark		x													Antsingora; Antsingora ambanivava; Antsingora fasika; Antsingora fotsy; Antsingora

																tasika; Antsingora vato
Rhynchobatus djiddensis	Giant Guitarfish			Sorobois		Lafitany										
Rhynchobatus spp.		x	Tandraly													
Rhinobatus sp.																Sorkay
Rhinobatos leucospilus	Garyspotted guitarfish	x														
Sphyrna lewini	Scalloped hammerhead	x	Antenohomaso	Viko	Viko; Palapalan-doha	Satraha; Amama	Viko	Viko; Palaloha	x	Antendro-maso	Antendro-maso	Antendro-maso	Antendro-maso	Antendro-maso; Satrana; Sorokay	Sorokay; Satrana	Antendro-maso; Antsingora
Sphyrna mokarran	Great hammerhead		Antenohomaso		Viko; Palapalan-doha	Satraha; Amama	Viko	Viko; Palaloha		Antendr-omaso	Antendro-maso	Antendro-maso	Antendro-maso	Antendro-maso; Satrana; Sorokay	Sorokay; Satrana	x
Sphyrna zygaena	Smooth Hammerhead			Viko												
Stegostoma fasciatum	Zebra shark	x	x	Miroro	Ntsaka	Razankiahia; Renieo	Ntsaka	Andrangita; Tandaly		x			Amboso	Amboso vandana	Vontsoro	Amboarano
Triaenodon obesus	Whitetip reef shark		Maro alahala											Atsantsavy; Atsantsama hery	Atsantsa satrana	

Table S4. Community data collectors’ and shark fishers’ attitudes to changes in the shark fishery. Data on changes in size, species and number of sharks was collected 2007 to 2008. Participative appraisals of the data from 2007 to 2012 were done in early 2013 to provide ranked reasons for changes in the number of sharks recorded during this period. Dash indicates data not collected in that village.

Village (Region)	**Year shark fishing commenced**	**Have you noticed a change in the size, species or number of sharks captured?**				**Ranked reasons given for fluctuations in recorded shark landings**
		Yes or No	**If yes: specify if it’s been an ‘increase’ or ‘decrease’, the order of size if possible and the time period over which this change has occurred**			
Ampasilava (1)	1995	Yes	Decrease	Numbers	Last 5 years	(1) Data not recorded (=2) Decrease in shark fishers (=2) Change in fishing gears (3) Changes in climate
Andavadoaka (1)	1987	Yes	Decrease	Size	Last 10 years	(1) Decrease in shark populations (2) Decrease in shark fishers (3) Changes in weather/season of abundance
Andranombala (1)	1993	Yes	Decrease	Numbers	Last 20 years	-
Ankitambagna (1)	1997	No				-
Antsepoke (1)	Before 1999	No				(=1) Data not recorded (=1) Migration of fishers (2) Decrease in shark populations
Belavenoke (1)	1992	Yes	Decrease	Size	Last 6 years	-
Bevato (1)	1992 or earlier	Yes	Decrease	Numbers and size	Last 5 years	-
Lamboara (1)	1995	No				(1) Migration of fishers (2) Data not recorded (3) Change in fisher activity
Nosy Be (1)	1991	Yes	Increase	Numbers		(1) Data not recorded (2) Migration of fishers (3) Change in fisher activity

Nosy Hao (1)	1997	Yes	Decrease	Numbers and size	Last 10 years	-
Nosy Lava (1)	1981	Yes	Decrease	Numbers and size	Last 20 years	-
Ampatike (2)	-	Yes	Decrease	Species and number	Last 8 years	(1) Migration of fishers (2) Data not recorded (3) Afraid to report catch
Ankevo (2)	-	-				(1) Data not recorded (2) Change in fisher activity (3) Change in fishing gears
Belalanda (2)	-	Yes	Decrease	Numbers	Last 10 years	-
Belagnora (2)	-	No				-
Belo-sur-Mer (2)	-	No				-
Betania (2)	-	-				(1) Data not recorded (2) Change in fisher activity (3) Change in fishing gears
Nosy Andriamitaroke (2)	-	Yes	Decrease	Numbers and size	Last 10 years	-
Nosy Be (2)	-	Yes	Decrease	Numbers and size	Last 5 years	-

Table S5: The number and percentage of sharks landed by each fishing gear.

Table S5a: The number and percentage of sharks landed across both regions by each fishing gear.

	2007		**2008**		**2009**		**2010**		**2011**		**2012**		**Total**	
Method	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**
Net (all)	79.6	735	73.0	1143	67.8	1642	91.4	2603	92.4	1309	90.2	2032	82.8	9464
Janoky (4 - 9 cm)	*0.1*	*1*	*0.0*	*0*	*8.8*	*213*	*37.0*	*1055*	*38.0*	*538*	*9.6*	*217*	*17.7*	*2024*
Jarifa (12 - 25 cm)	*3.7*	*34*	*27.1*	*424*	*18.7*	*453*	*5.9*	*168*	*5.4*	*77*	*2.9*	*65*	*10.7*	*1221*
Zdzd (8 -10 cm)	*67.7*	*625*	*32.7*	*512*	*15.9*	*386*	*41.4*	*1180*	*8.8*	*125*	*37.3*	*840*	*32.1*	*3668*
Zdzd and Jarifa	*0.3*	*3*	*0.3*	*4*	*0.0*	*0*	*0.1*	*3*	*0.0*	*0*	*0.0*	*0*	*0.1*	*10*
Net (2 - 5 cm)	*7.8*	*72*	*13.0*	*203*	*24.4*	*590*	*6.9*	*197*	*40.2*	*569*	*40.4*	*910*	*22.2*	*2541*
Hook and Line	14.4	133	17.8	279	24.9	602	4.4	124	3.6	51	6.6	149	11.7	1338
Longline	5.5	51	8.9	139	6.6	160	3.5	99	1.2	17	1.3	29	4.3	495
Beach seine	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.3	6	0.1	6
Spear	0.1	1	0.0	0	0.3	8	0.4	11	0.6	9	1.3	30	0.5	59
Speargun	0.2	2	0.2	3	0.4	10	0.4	11	1.3	19	0.3	7	0.5	52
Net, Hook and Line	0.0	0	0.0	0	0.0	0	0.0	0	0.7	10	0.0	1	0.1	11
Net and Speargun	0.0	0	0.1	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1
Unknown method	0.1	1	0.0	0	0.0	0	0.0	0	0.1	1	0.0	0	0.0	2
Total	100	923	100	1565	100	2422	100	2848	100	1416	100	2254	100	11428

Table S5b: The number and percentage of sharks landed across region 1 by each fishing gear.

	2007		**2008**		**2009**		**2010**		**2011**		**2012**		**Total**	
Method	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**
Net (all):	79.6	735	66.4	568	49.5	581	92.7	1431	91.1	782	90.2	1183	79.2	5280
Janoky (4 - 9 cm)	0.1	1	0.0	0	18.2	213	68.4	1055	62.7	538	16.5	216	30.4	2023
Jarifa (12 - 25 cm)	3.7	34	5.1	44	0.2	2	1.5	23	2.4	21	1.1	14	2.1	138
Zdzd (8 -10 cm)	67.7	625	41.1	351	8.4	98	14.8	229	13.2	113	54.8	719	32.0	2135
Net (2 - 5 cm)	7.8	72	20.2	173	22.8	268	7.8	121	12.8	110	17.8	234	14.7	978
Hook and Line	14.4	133	27.4	234	46.9	550	4.2	65	3.5	30	4.7	61	16.1	1073
Longline	5.5	51	5.8	50	2.0	24	1.6	25	2.0	17	2.2	29	2.9	196
Other	0.4	4	0.4	3	1.5	18	1.4	22	3.4	29	2.9	38	1.7	114
Total	100	923	100	855	100	1173	100	1543	100	858	100	1311	100	6663

Table S5c: The number and percentage of sharks landed across region 2 by each fishing gear. ND = Data collection had not started.

	2007		2008		2009		2010		2011		2012		Total	
Method	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**
Net (all):	ND	ND	81.0	575	84.9	1061	89.8	1172	94.4	527	90.0	849	87.8	4184
Janoky (4 - 9 cm)	ND	ND	0.0	0	0.0	0	0.0	0	0.0	0	0.1	1	0.0	1
Jarifa (12 - 25 cm)	ND	ND	53.5	380	36.1	451	11.1	145	10.0	56	5.4	51	22.7	1083
Zdzd (8 -10 cm)	ND	ND	22.7	161	23.1	288	72.9	951	2.2	12	12.8	121	32.2	1533
Net (2 - 5 cm)	ND	ND	4.2	30	25.8	322	5.8	76	82.3	459	71.7	676	32.8	1563
Hook and Line	ND	ND	6.3	45	4.2	52	4.5	59	3.8	21	9.3	88	5.6	265
Longline	ND	ND	12.5	89	10.9	136	5.7	74	0.0	0	0.0	0	6.3	299
Other	ND	ND	0.1	1	0.0	0	0.0	0	1.8	10	0.6	6	0.4	17
Total	ND	ND	100	710	100	1249	100	1305	100	558	100	943	100	4765

Chapter 4: Placing Madagascar's marine turtle populations in a regional context using community based monitoring

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Abstract

Madagascar is an important foraging ground for marine turtle populations in the Western Indian Ocean, yet the status of the island's nesting populations remain poorly documented. In this study, we assess the current status and trend in nesting throughout Madagascar including data recorded by a community-based monitoring project in the Barren Isles (western Madagascar). We contextualise findings in comparison with data from Madagascar's closest neighbouring states. Reports indicate that Madagascar's nesting populations have declined in many coastal sites over the last 10-20 years, with reports of >40 nesting sites with no known recordings since 2000. We estimate nesting in Madagascar is likely to be a minimum of 1200 nests.year^{-1}, with the largest recorded nesting populations (<1000 nests.year^{-1}) found on islands off the west and northern coasts. The majority of nesting populations, including those recorded by the community-based monitoring project in the Barren Isles, are relatively small, in the order of <50 nests.year^{-1}, yet potentially important sources of regional genetic diversity. Nesting on many of the islands (eg Tromelin, Europa) surrounding Madagascar have increased over the last 20 years, despite the fact that thousands of turtles, likely to have originated from these sites, are taken by fishers in the waters of Madagascar annually. We discuss the importance of protecting small nesting populations and how community-based monitoring could be an important tool for conserving remote and vulnerable populations of species such as marine turtles in Madagascar.

Introduction

The conservation and management of marine megafauna is a global challenge, often hampered by a lack of financial and human resources, with greater data deficiency in marine species (Schipper et al., 2008; Mangel et al., 2010; Lewison et al., 2014). In more remote regions, such as offshore islands and archipelagos, conservation and management can be more complicated, as their geographical location may make them both a popular fishing ground and a hotspot for migratory marine species (Sullivan et al., 2006; Brotons et al., 2008; Capietto et al., 2014), including endangered marine megafauna such as marine mammals, turtles and seabirds that are not only targeted directly but also suffer high mortality from bycatch (Lewison & Crowder, 2007; Pusineri & Quillard, 2008; Senko et al., 2014). Marine turtles face threats both in the sea and on land, when they come to nest, and as such are particularly vulnerable if nesting grounds are remote, attract a high number of fishers and are located in a region that lacks capacity for monitoring and enforcement.

The majority of marine turtle nesting sites in Madagascar are found on the west coast, closest to the most suitable foraging habitats, with higher concentrations of nesting on some of the larger islands in north-west Madagascar (Rakotonirina & Cooke, 1994; Bourjea et al., 2006; Metcalf et al., 2007). Nesting rates in Madagascar may have been historically lower than neighbouring islands (eg. Europa, Mayotte), but are known to have declined in the latter half of the 20th century (Frazier 1975; Rakotonirina, 1987; Rakotonirina & Cooke, 1994; Walker & Roberts, 2005). Rakotonirina and Cooke (1994) reported that nesting rates had declined for all species across Madagascar with two sites (one site was reported to host dozens of nesting olive ridleys) on the west coast of Madagascar having no nesting turtles since the mid-1980s. There have however, been interviews reporting increases in nesting in northern Madagascar (Mealla, 2011).

In Madagascar, all species of marine turtles are protected from domestic exploitation (Presidential Decree 2006-400). Coastal fishing communities however, continue to take all five species of marine turtle, estimated at 10,000 to 16,000 year^{-1} (Humber et al., 2011). The majority of turtles are taken at sea, although nesting females and eggs will be taken opportunistically (Rakotonirina & Cooke, 1994; Lilette, 2006). National laws are not enforced due to several factors, including a lack of implementation capacity, a reluctance to manage a fishery with such strong cultural links and the immensity of the Malagasy coastline and territorial waters (Okemwa et al., 2005).

Small nesting populations of marine turtles present challenges due to the logistical challenges of ensuring that a sufficient number of animals are encountered or protected, especially within remote environments (Mellors et al., 2008; Danielsen et al. 2009; Pilcher & Chaloupka, 2013). Furthermore, populations of species at low densities can suffer from decreased per capita population growth rate, known as the Allee effect or depensation (Allee et al., 1949), where a population declines to a point where it is no longer able to recover (Clarke, 1985). Evidence of depensation in marine species, including marine turtles, has been demonstrated in a few studies (Chaloupka 2004; Stoner & Ray-Culp, 2000; Liermann & Hilborn, 2001), but has also been found lacking in others (Myers et al., 1995; Bell et al., 2009; Liermann & Hilborn, 2001).

Community-based monitoring and participatory research have been shown to be effective in providing reliable scientific data whilst being cost-effective if well designed (Holck, 2008; Carvalho et al., 2009), in particular for small populations or low encounter rates (Gaidet et al. 2003; Humber et al. 2011). Furthermore they can help to raise interest and awareness amongst stakeholders, enhance learning, foster ownership of natural resources, and lead to greater buy-in for either current management regimes or catalyse the development of community-led natural resource management (Andrianandrasana et al., 2005; Fazey et al., 2010; Evely et al., 2011). Even in circumstances where community data has been shown to be less reliable than that of trained biologists, overall management recommendations can be similar, whilst also promoting and tightening an adaptive management cycle (Veitayaki, 1997; Uychiaoco et al., 2005). Overall these methods increase the chance of the development of accepted management and conservation measures which in turn allow for greater success through compliance and self-regulation (Silver & Campbell, 2005; Shackeroff & Campbell, 2007; Andriamalala & Gardner, 2010).

The use of participatory monitoring and research in marine turtle conservation and management has been widely used and has provided important data (Nichols et al., 2000; Humber et al., 2011; Garnier et al., 2012). Community-based conservation strategies are important within communities that have a vested interest in preserving turtle populations, especially where turtle fishing is a traditional livelihood and part of local cultural dynamics (Nichols et al., 2000; Havemann & Smith, 2007). Actively involving communities has also helped to reduce illegal take of nesting females and fishing bycatch (Garnier et al., 2012); in Cape Verde a recently developed community-based conservation programme has reduced the number of females killed by as much as 75% in one season (Dutra & Koenen, 2014). Community programmes also play an important role in creating jobs and providing an alternative source of income (Montoya & Drews, 2007).

This paper presents an overview of marine turtle nesting populations in Madagascar and the Western Indian Ocean, including new data recorded by the first community-based marine turtle nesting and protection programme in the Barren Isles, western Madagascar, a site about which little was previously known. To the authors' knowledge there has been no similar programme in Madagascar, although community-focussed programmes that promote locally-led conservation and fisheries monitoring do exist (Gibbons, 2013; Humber et al., 2011).

Methods

Nest monitoring

Study area

A community-based programme was established in the Barren Isles (Figure 1), an archipelago of nine islands off the west coast of Madagascar in the Mozambique Channel, to monitor, protect and gather baseline data on a known nesting population. Previous limited nesting surveys in the Barren Isles suggested there was a small but significant nesting population threatened by direct take from local and migrant fishers (Leroux, 2007).

The islands are located between 15 and 65 km south and west of the only major town in the remote Melaky region, Maintirano (Figure 1). The Barren Isles' coastal and marine ecosystem covers approximately 5000 km^2 and consists of a large diversity of marine and coastal habitats, including deep oceanic waters, coral reefs, mangrove forests, coral islands, sand cays and coastal dunes. Along with five marine turtle species, other species of conservation value include numerous shark and cetacean species and the coelacanth (*Latimeria chalumnae*) (Rosenbaum, 2003; Leroux, 2007; Van Canneyt et al., 2010; Cripps, 2011). The coral reef habitats are considered to be representative of the healthiest reefs in Madagascar (Cripps, 2011).

The Barren Isles supports a productive artisanal pelagic fishery (Cripps, 2011). The Isles have no permanent residents or villages but during the austral winter (April to November) increasingly large numbers of *Vezo* and *Sara* migrant fishers from along the west coast of Madagascar set up temporary camps on the islands to exploit the relatively rich marine resources (Cripps, 2009, 2011; Leroux et al., 2010), with some fishers travelling up to 1000 km, as they are faced with unabated declines of marine resources and deepening poverty in their home areas (Laroche et al., 1997; McVean et al., 2006; Cripps, 2009, INSTAT, 2010). All the islands are inhabited during this period, although one island, Nosy Mboro, has been protected through a local law since 2013, prohibiting people from staying overnight. Fishers from the nearby coastal communities also visit the islands for days at a time during the austral winter. Approximately 4000 traditional fishers (resident and migrant) exploit the Barren Isles ecosystem (Cripps, 2009; Blue Ventures, unpublished data). In-water and nesting marine turtles on islands are taken by migrant fishers (and resident fishers), as well as eggs consumed (Leroux 2007; Leroux *et al*., 2010).

Development of community monitoring and protection scheme

Data were collected by a team of eight community members (two per island) who were selected through an interview process in late 2011 to become turtle nest monitors. The team was trained in turtle species identification, nest identification, curved carapace length measurements (CCL) and photography, over six days in December 2011. This included both office and field training, and methods were based on those of *Les tortues marines du Sud Ouest de l'Océan Indien* (TORSOOI, www.torsooi.com), developed to promote harmonization and standardisation of data collection. A month of trial data collection was completed in December 2011. The team was supervised by a Project Coordinator based in Maintirano, who also visited the teams at least once a season on the islands to check on monitoring methods. A refresher training session was also held in November 2012.

Four islands were regularly surveyed between December and May each year from 2012 to 2014 (three seasons) (Table 1). Previous accounts and reports suggested this was the main nesting season and limited budgets prohibited year-long monitoring across all eight islands. Islands were chosen from accounts of nesting recorded by a previous research group and reports from the community, as well as size of island and feasibility of camping there for the monitoring periods. Three islands were monitored in all three seasons Nosy Abohazo, Nosy Dondosy, Nosy Andrano. However, although Nosy Mboro was monitored in 2011-2012, in 2013 a decree to protect nesting birds by the mayor of Maintirano forbade people from staying on the island. Therefore monitoring in 2012-2013 included the island of Nosy Mangily but due to low nesting rates, efforts in 2013-2014 were directed to the island of Nosy Lava. In 2012-2013, opportunistic trips were made to Nosy Mboro.

Surveys took place daily for 19 to 24 consecutive days with *ca*. 3 to 15 day intervals between monitoring periods to allow for restocking of supplies and recovery from the difficult living conditions. Shorter periods of monitoring (*ca.*10 days) occurred at the very beginning and end of the monitoring period, and an extended period with no monitoring occurred in December 2013. Beach walks were conducted nightly over two hours during high tide, with two monitors covering half of the island each. The largest island, Nosy Lava, has approximately 2.46 km of sandy beach, and the smallest island, Nosy Dondosy, 0.83 km. Beach walks were also conducted every morning before the first high tide.

During surveys, new nesting activities were recorded. If the nesting adult was not observed then species and clutch deposition were ascertained by inference based on the size and shape of tracks. When a turtle was observed she was left to lay her clutch after which curved carapace length (CCL) measurement was taken. Nests were marked with wooden stakes. Locations of all activities were recorded as within a predetermined zone (range per island dependent on size: 4-8).

On the first day of surveys at the beginning of the season, or after the break between monitoring sessions, beaches were checked on arrival. It was noted that these nests were recorded on the first day of the survey period, and as their lay date could not be accurately determined they were removed from temporal analyses.

Interpolation of nest data

In order to assess the seasonality for the three islands monitored each season (Nosy Abohazo, Nosy Andrano, Nosy Dondosy), gaps in monitoring were filled by interpolation of data by island. An average of 14 days of nesting counts, seven days either side of the monitoring gap, was calculated and used to create an estimated nesting count for those days when surveys were not conducted within the monitoring period.

Current nesting overview

A review of the current (post 2000) status of nesting populations across Madagascar and surrounding countries in the Western Indian Ocean region was carried out (Figures 2, 3), through an extensive literature and database search (eg. Indian Ocean South East Asia Marine Turtle Memorandum of Understanding, IOSEA; The State of the World’s Sea Turtles, SWOT). Further key partners were contacted in Madagascar for any additional or missing information, and current nesting accounts at three of Blue Ventures Conservation conservation sites (sites 11, 12 and 13 on Figure 2) were also recorded through participatory mapping exercises and key informant interviews (see section: Historical nesting reports).

Historical nesting reports

To help contextualise our findings, historical (pre 2000) nesting accounts from across Madagascar were located through an extensive search of papers and grey literature. Historical (and current) nesting accounts were also recorded through participatory mapping exercises and through key informant interviews. Participatory mapping occurred in the region surrounding the village of Andavadoaka (Figure 2, label o) in April to May 2011. Elders in 10 villages were shown maps of the region and asked to point out where they had last seen a turtle nest, the year and species if known. Interviews in Belo-sur-Mer (Figure 2, label f) and Maintirano/Barren Isles were held in March and May of 2013, respectively. The Andavadoaka and Belo-sur-Mer regions are both home to *Vezo* fishers who rely on marine resources almost exclusively for their livelihoods. Although potential species at historic nesting sites were given, these data were not included in maps due to potential errors, only the site and year (which was categorised as pre or post 2000).

Results

Current nesting in the Barren Iles

A total of 173 nesting emergences were observed over three nesting seasons between January 2012 and May 2014 and 135 nests were recorded (Table 1). Over the three nesting seasons, an average of 33.6 green turtle nests.year^{-1} (2011/12: 19 nests, 2012/13: 45 nests, 2013/14: 37 nests) and 11 hawksbill turtle nests.year^{-1} (2011/12: 7 nests, 2012/13: 15 nests, 2013/14: 11 nests) were recorded at our study sites. The majority of nests were identified as green turtle (74.8%, n = 101) and hawksbill turtle nests (24.4%, n = 33), with one olive ridley nest confirmed. Two loggerhead turtle nesting emergences were observed but no nesting was recorded.

Seasonality

Nesting activity was detected in each month of the monitoring period (Figure 4). The number of green turtle nests peaked in February and March in the first two seasons but in December and May in the 2013-2014 season (Figure 4; see Figure S1 in Supporting Information). Hawksbill nesting was not recorded in every month in each season but peaked in December to February in each monitoring season (Figure 4; S1).

Location of nests

The majority of nesting activity, from the three islands monitored consistently, took place on Nosy Abohazo (60.7%, n = 68) with all but four nests identified as those of green turtles (Table 1; Figure 3). Nosy Andrano accounted for 32.1% (n = 36) of nesting activity with 58.3% (n = 21) green and 41.7% (n = 15) hawksbill turtles.

Adult turtles

Throughout the survey period a total of 72 turtles were measured. The mean curved carapace length (CCL) of nesting green turtles was 105.6 cm ± 6.6 (range 94-126 cm, n = 58), whilst hawksbill turtles measured 84.4 cm ± 12.2 (range 52-97, n = 13). The one olive ridley measured had a CCL of 69 cm.

Loss of nests

No loss of nests from eggs being taken or illegal killing of nesting females was observed on the islands whilst monitors were present. However, six nests may have been raided for eggs on Nosy Abohazo whilst monitors were not present but it was not possible to confirm this. Further reports of nests being raided on unmonitored islands were received by the team and Project Coordinators, as well as harvesting of adult turtles illegally by fishers for local consumption within villages and to satisfy orders from local businessmen.

Historic nesting

Historic known nesting sites within Madagascar are also shown in Figure 2. Reports from interviews and found in papers and reports show that there were at least 44 known former nesting sites in Madagascar (Figure 2, Table S3). The size of nesting aggregations at these sites at time of recording is likely to have been relatively small (<10 nests.year^{-1}). Interviews with elders in the regions surrounding the villages Andavadoaka and Belo-sur-Mer highlighted that there has been a decline in nesting since memory (1960s). In the Maintirano region it was reported that Nosy Dondosy used to host much larger numbers of nesting turtles but is now one of the most heavily populated by fishers, and elders attributed the decline in nesting to increased human presence since 1999. A similar situation was reported for the island of Nosy Vao, 70 km north of Maintirano, which now hosts fisher settlements. In the past, green and hawksbill turtles also nested on the mainland coast north and south of Maintirano. Today, there are no reports of nests in this region.

National and regional nesting

National nesting

Sites in Madagascar that still host regular nesting activity are concentrated in the northwest (Figure 2), where hotspots of nesting remain on islands. However, nesting is fairly low throughout Madagascar, with most sites estimated to have <50 nest.year^{-1}. In southwest Madagascar, reports of nesting have reduced to individual reports of sporadic nesting, in particular at two sites where interviews were conducted (site 11: Andavadoaka, and site 12: Belo-sur-Mer regions) (Figure 2; see Tables S1 and S3 in Supporting Information). We estimate minimum nesting for all of Madagascar to be approximately 1200 nests.year^{-1}, of which approximately 74% (n = 888) and 18% (n = 220) have been recorded as green and hawksbill, respectively, and 7% (n = 80) were unidentified.

Regional nesting

Madagascar is surrounded by protected nesting populations on islands and coastlines, in particular the *Îles Éparses* (“Scattered islands”: Tromelin, Glorioso Islands and Europa) (Figure 3). The size of nesting populations and annual nesting are greater than that found in Madagascar and are in the range of 1000-5000 nests.year^{-1} or nesting females.year^{-1}, with nesting of similar magnitude also occurring in Mayotte and the northeast coast of South Africa (see Table S2 in

Supporting Information). The majority (82%, n = 18,636) of nesting activities recorded were green and located on the Îles Éparses, Mayotte and the Comores, with loggerheads accounting for 16% (n = 3,701) of recordings on mainland Africa (South Africa and Mozambique).

Discussion

Historic versus current nesting indicates a decline

Nesting numbers in Madagascar may have been historically low, but there is currently only one nesting site estimated to have more than 500 nests.year^{-1} (Figure 2: Study g, Nosy Hara). Nesting has declined in particular on the mainland, due to systematic collection of eggs and nesting females (Rakotonirina & Cooke, 1994; Walker & Roberts 2005; Cooke, 2003). Furthermore over 40 sites have been recorded, via a literature search and through interviews in this study, as historic nesting sites, with no nesting known since 2000. Nesting at multiple coastal sites in southwest Madagascar have declined so that nesting is now rare or not known since 2000-2001 (Walker & Roberts, 2005); and in southeast Madagascar there used to be large numbers of loggerheads nesting in the 1970s, but only 23 nests recorded in the 2001-2002 nesting season of which half were illegally taken (Gladstone et al., 2003). Declines were reported in this study at all coastline sites, and also on the coastline near Maintirano. Madagascar's islands (eg. Nosy Iranja, Nosy Hara) remain the most important nesting sites within national waters (Bourjea et al., 2006; Metcalf et al., 2007). However, nesting on Nosy Ve, one of the five small islands on the west coast protected in 1923 was last reported in 1986 (Cooke, unpublished report), and at Nosy Vao, an island 70 km north of Maintirano, nesting is no longer known (fishers pers. comm.).

Madagascar's turtles in a regional context

There are significant populations of nesting turtles on the islands surrounding Madagascar, many of which are uninhabited and fully protected (eg. Europa, Tromelin) (Figure 3, Table S2). Green turtle populations nest in significant numbers in the South West Indian Ocean (SWIO) (eg. Europa 7-10,000 nesters.year^{-1}; Mayotte 4000-6000 nesters.year^{-1}), making the region an extremely important region for green turtle nesting (Bourjea et al., 2007; Elst et al. 2012); whilst the west coast of Madagascar is a known foraging ground for green turtles from these nesting populations, such as the Comores, Europa, Glorioso Islands, Mayotte, Mozambique and Tromelin, as demonstrated by tag returns (Figure 3) (Ifremer & Kelonia, 2014).

Whilst numbers of turtles taken by fishers in Madagascar's waters appears to have remained at the same levels since the 1970s (Hughes 1971; Frazier 1980; Rakotonirina & Cooke, 1994; Humber et al., 2011), many rookeries in the SWIO also report increases in nesting since Frazier's (1975) estimate of fewer than 5500 green turtles nesting in the western Indian Ocean, in particular where nesting turtles have enjoyed long-term protection, with numbers in the region now likely to be in excess of 27,000 nesters.yr^{-1} (Elst et al., 2012).

Recovery of once depleted nesting populations has not been limited to the SWIO but has occurred globally (Troëng & Rankin, 2005; Chaloupka & Balazs, 2007; Stokes et al., 2014). Green turtle clutches have increased sixfold on Ascension Island over the last 40 years and the population by 285% (Broderick et al., 2006; Weber et al., 2014); there has been 10% per annum population growth of neophyte hawksbill populations in Antigua (Richardson et al., 2006); recovery of one the largest remaining loggerheads nesting populations in Brazil (Marcovaldi & Chaloupka, 2007); US leatherback population increasing 13% per annum in the US Virgin Islands (Dutton et al., 2005); as well as increases in olive ridley (Márquez-M et al., 1996; Metcalf et al., 2015) and Kemp's Ridleys (Márquez et al., 1999).

Despite regional and global recoveries of many nesting populations due to increased protection and cessation of commercial harvesting, those in Madagascar appear to have remained at the same level or decreased. Nesting populations in Madagascar could represent remnants of once larger nesting populations, compared to anecdotal reports of nesting levels in early accounts (Frazier, 1975). Many nesting populations globally represent depleted populations compared to historical numbers (Bell et al., 2007; Richardson et al., 2009) and ranges with 70% of historic nesting sites lost entirely or reduced to dangerously low populations (McClenachan et al., 2006; McGowan et al., 2008).

Consistent high levels of take could continue to keep nesting populations at low levels in Madagascar, and the Barren Isles even if most turtles are fished elsewhere along the coastline, endangering the future of the remaining native turtle populations of Madagascar, as the impact of small scale fisheries on marine turtle mortality can be significant (Alfaro-Shigueto et al., 2011; Humber et al., 2011).

Importance of small nesting populations

This study suggests that the Barren Isles is one of Madagascar's few, remaining important nesting sites. While larger nesting sites exist in northern Madagascar, there are no long term studies that indicate whether these sites are in decline or recovering, with the exception of Nosy Iranja where regular monitoring since 2000 indicates an increase in nesting numbers, and which benefits from a partnership between scientists and a hotel that owns the island (Bourjea et al., 2006, J. Bourjea pers.comm.). Many smaller nesting populations in Madagascar have already declined or been extirpated. However, McClenachan et al. (2006) warn against focusing attention solely on only large nesting populations. Relatively small nesting populations (eg. ~100 nests.year^{-1}) have been shown to be both nationally and regionally important (Rees et al., 2008; Richardson et al., 2009), that they can recover rapidly (Hays, 2004); and that their protection should be encouraged to reduce the risk of focussing on a few exceptional nesting beaches to the detriment of smaller, historically important nesting beaches (McClenachan et al., 2006; Bell et al., 2009).

The median number of nests recorded in the Barren Isles was 48 in the 2013-2014 season, but ranged from 27 to 60 nests.year^{-1} during the monitoring period. It would appear that the number of greens nesting annually (74.8% of nests) is more stable between years than we would normally expect (Broderick et al., 2001). Although it is too early to be able to draw any conclusions as to the trend of nesting numbers in the Barren Isles, we hope that any future increases or decreases will be detected as long as survey effort is focussed during the peak of nesting (Jackson et al., 2008) and for long enough to overcome the problem of interannual variation in nest numbers (Broderick et al., 2001). Monitoring was not performed outside the months of December to May, and although this is considered the peak nesting period, reports of nesting within June to November have been received. Unpublished data show that up to 26 nests were recorded in one month on intensive monitoring across five islands from November 2009 to December 2009, indicating total nesting could be two to three orders higher (G. Leroux, unpublished data) and that numbers presented in this study maybe a minimum.

Nesting populations in the Barren Isles are also likely to have declined and in the past it is reported that all the islands, except for Nosy Ampasy, Nosy Marify and Nosy Manandra (which are sand banks), had nesting populations. Interviews with local fishers and elders showed that Nosy Dondosy used to be the second most preferred nesting site, but today it hosts only a few nests per season. Interviewees attributed the decline in nesting to increase human presence since ~1999 and growing numbers of migrant fishers. Cripps (2011) also highlights growing numbers of migrant fishers settling on the Barren Isles since around 2000 which have negatively impacted nesting colonies of seabirds, nesting turtles and trees that once existed on certain islands. The Barren Isles are not only threatened by increasing fishing pressure, but also increasing outside commercial interests from semi-industrial and industrial fisheries, targeting high value species such as sharks and sea cucumbers, and commercial mining operations targeting the island’s guano deposits (Cripps, 2009, 2011).

Benefits of community-based monitoring

This study has also presented the results of the first long-term community-based monitoring of nesting turtles in Madagascar, providing detailed data on nesting activity on one of its small and remote nesting populations. There is a severe lack of up to date data on nesting in Madagascar, as well as a lack of capacity to carry out monitoring and research to address critical management gaps (Humber & Hykle, 2011; IOSEA, 2014). This study further demonstrates that communities can play a pivotal role in plugging gaps in data and conservation management, providing valid research data and management capacity, particularly at remote nesting sites (Alfaro-Shigueto et al. 2012; Garnier et al., 2012; Dutra & Koenen, 2014).

The benefits of community-based monitoring extend further than the means to generate data (Table 2). Community teams on nesting beaches can reduce incidences of nesting females, and nests, being taken both during and after the monitoring period (Smith & Otterstrom, 2009; Garnier et al., 2012; Girard & Breheret, 2013). Reports from the teams within this study is that the number of nests disturbed was low, and that a visit to Nosy Lava in the 2012-2013 nesting season (not part of regular monitoring that year) showed that all nests found had been disturbed. Reports from pre-2011 indicated that nests were raided frequently (G. Leroux, unpublished data). Contrary to Senko et al. 2011, as yet there has also been no known conflict within the community between those participating in this programme, and their peers that may continue to illegally take eggs and adults.

Community-based projects improve capacity to monitor and manage natural resources, whilst building trust and buy-in for wider natural resource management (Danielsen et al., 2005, 2009; Carvalho et al., 2009). This is particularly important in this region as a community-managed marine protected area (MPA) is under development, with NGO Blue Ventures leading capacity building. Conflict exists in Madagascar between local communities who traditionally hunt turtles (now illegal) and authorities, and could have been a major source of tension between the communities and Blue Ventures. However, this programme has helped to remove this potential area of conflict by building trust and demonstrating that Blue Ventures is not a prosecuting body (Table 2). Legislation in Madagascar permits the transfer of natural resource management rights to communities, and as such, there has been an important growth of bottom-up conservation and management initiatives (Rakotoson & Tanner, 2006; Andriamalala & Gardner 2010; Rocliffe et al., 2014).

However there are limitations to the level of data that can be collected within community-based programmes (Table 2). In this study it is apparent that the whole nesting season has not been captured, yet year round assessment is prohibited by the cost versus the level of nesting, and the fact that community members need to return to fishing during the austral winter. It is likely that the nesting season starts in November (G. Leroux, unpublished data), and that olive ridley nesting also remains on the adjacent coastline south of Ampandikoara (fishers pers. comms).

Conclusion

Madagascar’s remaining nesting turtle populations are vital to protect. To monitor and protect nesting of multiple species, across scattered small, remote populations would require significant financial resources and capacity, which are currently unavailable at the local or national level. However, this project, with focussed months of fieldwork by community members, has provided reliable and valuable data on the size of nesting, whilst also protecting nests and females. Increasing the protection of turtles within Madagascar is of growing importance with reports of new markets for turtles and their shell (Repoblikan’i Madagasikara, 2013).

This project has also protected a site of regional importance for green and hawksbill turtles in the Western Indian Ocean, and made significant progress towards protecting this site in the longer term with official temporary protection for the MPA now granted (Blue Ventures Conservation, 2014). However, the fact that Madagascar takes numerous foraging turtles could undermine conservation efforts elsewhere in the WIO (Mortimer et al., 2007), and have reduced the potential increase in nesting observed at the rookeries surrounding Madagascar. At the same time, these protected turtle populations could be the basis of a regional sustainable harvest, whilst also alleviating some pressure on Madagascar’s remaining nesting populations. However, the politics of whether one country should benefit from another country’s protected turtle populations will remain a contentious issue (Mortimer et al., 2007; Richardson et al., 2009; Lagueux et al., 2014). In order to protect Madagascar’s remaining nesting populations, the issue of reducing illegal take must also be addressed through strengthening legislation in place and empowering communities and NGOs to manage marine turtle populations and their marine resources (Evely 2011; Harris, 2011; Gibbons, 2013).

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References

Alfaro Shigueto, J., Mangel, J., Bernedo, F., Dutton, P. H., Seminoff, J. A. & Godley, B. (2011) Small-scale fisheries of Peru: a major sink for marine turtles in the Pacific. *Journal of Applied Ecology,* **48,** 1432–1440.

Alfaro-Shigueto, J., Mangel, J., Dutton, P.H., Seminoff, J.A. & Godley, B. (2012) Trading information for conservation: a novel use of radio broadcasting to reduce sea turtle bycatch. *Oryx*, **46**, 332-339.

Allee, W. C., Emerson, A. E., Park, O., Park, T. & Schmidt, K. P. (1949) *Principles of animal ecology,* Saunders, Philadelphia, Pennsylvania.

Allen, Z., C, Shah, N. J., Grant, A., Derand, G.-D. & Bell, D. (2010) Hawksbill turtle monitoring in Cousin Island Special Reserve, Seychelles: an eight-fold increase in annual nesting numbers. *Endangered Species Research,* **11,** 195-200.

Allison, G. (2008) *De la ponte à l'éclosion : suivi de la reproduction de deux espèces menacées de tortues marines, la tortue verte et la tortue imbriquée, sur l'île de Nosy Iranja, Madagascar*. Master 2 Biodiversité des Ecosystèmes Tropicaux, Université de La Réunion.

Andriamalala, G. & Gardner, C. J. (2010) L'utilisation du dina comme outil de gouvernance des ressources naturelles : leçons tirés de Velondriake, sud-ouest de Madagascar. *Tropical Conservation Science,* **3,** 447-472.

Andrianandrasana, H.T., Randriamahefasoa, J., Durbin, J., Lewis, R.E. & Ratsimbazafy, J.H. (2005) Participatory ecological monitoring of the Alaotra wetlands in Madagascar. *Biodiversity and Conservation*, **14**, 2757–2774.

Bell, C. D., Blumenthal, J. M., Broderick, A. & Godley, B. (2009) Investigating Potential for Depensation in Marine Turtles: How Low Can You Go? *Conservation Biology,* **24,** 226–235.

Blue Ventures Conservation (2014) *Indian Ocean's largest community-managed MPA established. Blue Ventures Conservation*. http://blueventures.org/indian-oceans-largest-community-managed-mpa-established/ [accessed 30 November 2014].

Bourjea, J., Ciccione, S. & Ratsimbazafy, R. (2006) Marine turtle surveys in Nosy Iranja Kely, North-Western Madagascar. *Western Indian Ocean Journal of Marine Science,* **5,** 209 - 212.

Bourjea, J., Frappier, J., Quillard, M., Ciccione, S., Roos, D., Hughes, G. & Grizel, H. (2007) Mayotte Island: another important green turtle nesting site in the southwest Indian Ocean. *Endangered Species Research,* **3,** 273–282.

Broderick, A. C., Frauenstein, R., Glen, F., Hays, G. C., Jackson, A. L., Pelembe, T., Ruxton, G. D. & Godley, B. J. (2006) Are green turtles globally endangered? *Global Ecology and Biogeography,* **15,** 21-26.

Broderick, A., Godley, B. & Hays, G. C. (2001) Trophic status drives interannual variability in nesting numbers of marine turtles. *Proceedings of the Royal Society of Biological Sciences,* **268,** 1481-1487.

Brotons, J. M., Grau, A. M. & Rendell, L. (2008) Estimating the impact of interactions between bottlenose dolphins and artisanal fisheries around the Balearic Islands. *Marine Mammal Science,* **24,** 112-127.

Capietto, A., Escalle, L., Chavance, P., Dubroca, L., Delgado de Molina, A., Murua, H., Floch, L., Damiano, A., Rowat, D. & Merigot, B. (2014) Mortality of marine megafauna induced by fisheries: Insights from the whale shark, the world's largest fish. *Biological Conservation*, **174**, 147-151.

Carvalho, A. R., Williams, S., January, M. & Sowman, M. (2009) Reliability of community-based data monitoring in the Olifants River estuary (South Africa). *Fisheries Research,* **96,** 119-128.

CEDTM (2001) *Mission a Manompana: Côte Est de Madagascar 3 - 9 août 2001*. Centre d'Etude et de Découverte des Tortues Marines (CEDTM), La Réunion.

Chaloupka, M. (2004) Exploring the metapopulation dynamics of the southern Great Barrier Reef green turtle stock and possible consequences of sex-biased local harvesting. In *Species Conservation and Management: Case Studies* (eds H. Akçakaya, M. Burgman, O. Kindvall, C. Wood, P. Sjogren-Gulve, J. Hattfield & M. McCarthy), pp. 340-354. Oxford University Press, New York.

Ciccione, S. & Bourjea, J. (2006) Nesting of Green Turtles in Saint Leu, Réunion Island. *Marine Turtle Newsletter,* **112,** 1-3.

Clark, C. W. (1985) *Bioeconomic modelling and fisheries management,* John Wiley and Sons, New York.

Cooke, A., Lutjeharms, J. & Vasseur, P. (2003) Marine and coastal ecosystems. In *The natural history of Madagascar* (eds S. Goodman & J. Benstead), pp. 179-209. Chicago University Press, Chicago.

Cripps, G. (2009) *Understanding migration amongst small-scale fishers in Madagascar.* Blue Ventures Conservation Report for ReCoMaP service contract PE2/014/2008. Blue Ventures Conservation, London, UK.

Cripps, G. (2011) *Feasibility study on the protection and management of the Barren Isles ecosystem, Madagascar*. Blue Ventures Conservation, London, UK.

Danielsen, F., Burgess, N.D. & Balmford, A. (2005) Monitoring matters: examining the potential of locally-based approaches. *Biodiversity and Conservation* **14**, 2507–2542.

Danielsen, F., Burgess, N.D., Balmford, A., Donald, P.F., Funder, M., Jones, J.P.G., Alviola, P., Balete, D.S., Blomley, T., Brashares, J., Child, B., Enghoff, M., Fjeldså, J., Holt, S., Hübertz, H., Jensen, A.E., Jensen, P.M., Massao, J., Mendoza, M.M., Ngaga, Y., Poulsen, M.K., Rueda, R., Sam, M., Skielboe, T., Stuart-Hill, G., Topp-Jørgensen, E. & Yonten, D. (2009) Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology*, **23**, 31-42.

Dutra, A. & Koenen, F. (2014) Community-based conservation: the key to protection of marine turtles on Maio Island, Cape Verde. *Oryx*, **48**, 325-325.

Dutton, P. H., Chaloupka, M. & Boulon, R. H. (2005) Increase of a Caribbean leatherback turtle *Dermochelys coriacea* nesting population linked to long-term nest protection. *Biological Conservation,* **126,** 186–194.

Elst, R. v. d., (Editor), Fennessy, S., Everett, B., Mackay, F., Floros, C., Schleyer, M., Kiszka, J., Bourjea, J. & Wanless, R. (2012) *Mainstreaming biodiversity in fisheries management: a retrospective analysis of existing data on vulnerable organisms in the South West Indian Ocean*. Prepared for the South West Indian Ocean Fisheries Project (SWIOFP). Oceanographic Research Institute, Durban, South Africa.

Evely, A., Pinard, M., Reed, M.S. & Fazey, I. (2011) High levels of participation in conservation projects enhance learning. *Conservation Letters*, **4**, 116-126.

Fazey, I., Kesby, M., Evely, A., Latham, I., Wagatora, D., Hagasua, J.-E., Reed, M.S. & Christie, M. (2010) A three-tiered approach to participatory vulnerability assessment in the Solomon Islands. *Global Environmental Change*, **20**, 713-728.

Frazier, J. (1980) Exploitation of Marine Turtles in the Indian Ocean. *Human Ecology*, **8**, 329-370.

Frazier, J. G. (1975) Marine turtles of the Western Indian Ocean. *Oryx,* **13,** 164-175.

Gaidet, N., Fritz, H. & Nyahuma, C. (2003) A participatory counting method to monitor populations of large mammals in non-protected areas: a case study of bicycle counts in the Zambezi Valley, Zimbabwe. *Biodiversity and Conservation,* **12,** 1571–1585.

Garnier, J., Hill, N., Guissamulo, A., Silva, I., Witt, M. & Godley, B. (2012) Status and community-based conservation of marine turtles in the northern Querimbas Islands (Mozambique). *Oryx*, **46**, 359-367.

Gibbons, E. (2013) *The Rufford Small Grants Foundation Final Report. FANO project.* Available at: http://www.rufford.org/projects/emma_gibbons [accessed 10 November 2014]. The Rufford Foundation, London.

Girard, A. & Breheret, N. (2013) The Renatura sea turtle conservation program in Congo. *Munibe Monographs. Nature Series*, **1**, 65-69.

Gladstone, N., Andriantahina, F. & Soafiavy, B. (2003) *Azafady Project Fanomena – Marine Turtle Conservation and Research in Southeast Madagascar. Report on Activities and Findings in the 2001-2002 Nesting Season*. Azafady, London, UK.

Harris, A. (2011) Out of sight but no longer out of mind: a climate of change for marine conservation in Madagascar. *Madagascar Conservation and Development,* **6,** 7-14.

Havemann, P. & Smith, R. (2007) *Community Based Management of Dugong and Turtle Fisheries. Safe-guarding culture for future generations — joining together to protect dugong and turtle fisheries for the Torres Strait*. Summary of TSRA Torres Strait Dugong and Marine Turtle Project Governance and Policy Review. James Cook University, Townsville, Australia.

Hays, C. G. (2004) Good news for sea turtles. *Trends in Ecology and Evolution,* **19,** 349-351.

Holck, M.H. (2008) Participatory forest monitoring: an assessment of the accuracy of simple cost–effective methods. *Biodiversity and Conservation*, **17**, 2023–2036.

Hughes, G.R. (1971) Sea turtle research and conservation in South East Africa In: *Proceedings of the 2nd working meeting of marine turtle specialists*, pp. 57-67. International Union for the Conservation of Nature and Natural Resources. Supplementary Papers, No 31, Morges, Switzerland.

Humber, F. & Hykle, D. (2011) *Report on the workshop for the adoption of a management and conservation plan for marine turtles in Madagascar*. Blue Ventures Conservation and IOSEA, London, UK.

Humber, F., Godley, B.J., Ramahery, V. & Broderick, A.C. (2011) Using community members to assess artisanal fisheries: the marine turtle fishery in Madagascar. *Animal Conservation*, **14**, 175–185.

Ifremer & Kelonia (2014) *Vidéos des migrations des tortues vertes*. Available at: http://wwz.ifremer.fr/lareunion/Les-projets/Tortues-Marines/DYMITILE/Trajectoires-en-video-des-tortues-vertes [accessed 30 September 2014].

INSTAT (Institut National de la Statistique) (2010) *Estimations de la population de Madagascar*. INSTAT, Antananarivo, Madagascar.

IOSEA (2011) *IOSEA site/threats reporting system*. http://iosea-reporting.org/test/reporting/ShowQThreats.asp [accessed 24th November 2014].

IOSEA (2014) Overview of IOSEA MoU Implementation. Synthesis of national reports as at 21 July 2014. MT-IOSEA/SS.7/Doc. 6 Agenda item 7a. In *Seventh Meeting of the Signatory States* pp. 33. Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA), Bonn.

Jackson, A. L., Broderick, A., Fuller, W. J., Glen, F., Ruxton, G. D. & Godley, B. (2008) Sampling design and its effect on population monitoring: How much monitoring do turtles really need? *Biological Conservation,* **141,** 2932–2941.

Lagueux, C.J., Campbell, C.L. & Strindberg, S. (2014) Artisanal Green Turtle, *Chelonia mydas*, Fishery of Caribbean Nicaragua: I. Catch Rates and Trends, 1991–2011. *PLoS ONE*, **9**, e94667. doi:10.1371/journal.pone.0094667.

Laroche, J., Razanoelisoa, J., Fauroux, E. & Rabenevanana, M. (1997) The reef fisheries surrounding the south-west coastal cities of Madagascar. *Fisheries Management and Ecology* **4,** 285-299.

Lauret-Stepler, M., Bourjea, J., Roos, D., Pelletier, D., Ryan, P., Ciccione, S. & Grizel, H. (2007) Reproductive seasonality and trend of *Chelonia mydas* in the SW Indian Ocean: a 20 yr study based on track counts. *Endangered Species Research,* **3,** 217-227.

Lauret-Stepler, M., Ciccione, S. & Bourjea, J. (2010) Monitoring of marine turtles reproductive activities in Juan de Nova, Eparses Islands, South Western Indian Ocean, based on tracks count and width. *Indian Ocean Turtle Newsletter,* **11**.

Leroux, G. (2007) Tortues Marines: L'Espoir en Marche. *Univers Maoré,* **8,** 32 - 43.

Leroux, G., Rakotonirina, B., Ciccione, S., Hawawini, S. & Campillo, A. (2010) First report of *Chelonia mydas* affected by cutaneous fibropapillomatis on the West coast of Madagascar. *Indian Ocean Turtle Newsletter,* **11,** 13-17.

Lewison, R. & Crowder, L.B. (2007) Putting Longline Bycatch of Sea Turtles into Perspective. *Conservation Biology*, **21**, 79–86.

Lewison, R., Crowder, L.B., Wallace, B.P., Moore, J.E., Cox, T., Zydelis, R., McDonald, S., DiMatteo, A., Dunn, D.C., Kot, C.Y., Bjorkland, R.A., Kelez, S., Soykan, C., Stewart, K., Sims, M., Boustany, A., Read, A.J., Halpin, P., Nichols, W.J. & Safina, C. (2014) Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots. *Proceedings of the National Academy of Sciences of the United States*, **111**, 5271–5276.

Liermann, M. & Hilborn, R. (2001) Depensation: evidence, models and implications. *Fish and Fisheries,* **2,** 33-58.

Lilette, V. (2006) Mixed results: conservation of the marine turtle and the red-tailed tropicbird by Vezo semi-nomadic fishers. *Conservation and Society,* **4,** 262–286.

Mangel, J.C., Alfaro-Shigueto, J., Van Waerebeek, K., Cáceres, C., Bearhop, S., Witt, M. & Godley, B.J. (2010) Small cetacean captures in Peruvian artisanal fisheries: High despite protective legislation. *Biological Conservation* **143**, 136–143.

Marcovaldi, M. A. & Chaloupka, M. (2007) Conservation status of the loggerhead sea turtle in Brazil: an ecouraging outlook. *Endangered Species Research,* **3,** 133-143.

Márquez, R., Díaz, J., Sanchez, M., Burchfield, P., Leo, A., Carrasco, M., Peña, J., Jiménez, C. & Bravo, R. (1999) Results of the Kemp's Ridley Nesting Beach Conservation Efforts in México. *Marine Turtle Newsletter,* **85,** 2-4.

Márquez-M, R., Peñaflores, C. & Vasconcelos, J. (1996) Olive Ridley Turtles (*Lepidochelys Olivacea*) Show Signs of Recovery at La Escobilla, Oaxaca. *Marine Turtle Newsletter,* **73,** 5-7.

McClenachan, L., Jackson, J. B. C. & Newman, M. J. H. (2006) Conservation implications of historic sea turtle nesting beach loss. *Frontiers in Ecology and the Environment,* **4,** 290–296.

McGowan, A., Broderick, A., Frett, G., Gore, S., Hastings, M., Pickering, D., Wheatley, D., White, J., Witt, M. & Godley, B. (2008) Down but not out: marine turtles of the British Virgin Islands. *Animal Conservation,* **11,** 92-103.

McVean, A., Walker, R. & Fanning, E. (2006) The traditional shark fisheries of southwest Madagascar: A study in the Toliara region. *Fisheries Research,* **82,** 280-289.

Mealla, R.A. (2011) *Investigating marine turtle nesting sites, local perceptions and conservation strategies in Northern Madagascar*. MSc Ecology, Evolution and Conservation, Imperial College London, London.

Mellors, J. E., McKenzie, L. J. & Coles, R. G. (2008) Seagrass-Watch: Engaging Torres Strait Islanders in marine habitat monitoring. *Continental Shelf Research,* **28,** 2339-2349.

Metcalf, J., Hampson, K., Andriamizava, A., Andrianirina, R., Cairnes, T., Gray, A., Ramiarisoa, C. & Sondotra, H. (2007) The importance of north-west Madagascar for marine turtle conservation. *Oryx*, **41**, 232-238.

Metcalf, K., Agamboué, P. D., Augowet, E., Boussamba, F., Cardiec, F., Fay, J. M., Formia, A., Kema, J. R. K., Kouerey, C., Mabert, B. D. K., Maxwell, S. M., Minton, G., Mounguéngui Mounguéngui, G. A., Moussounda, C., Moukoumou, N., Manfoumbi, J. C., Nguema, A. M., Nzegoue, J., Parnell, R. J., du Plessis, P., Sounguet, G.-P., Tilley, D., Verhage, S., Viljoen, W., White, L., Witt, M. & Godley, B. (2015) Going the extra mile: Ground-based monitoring of olive ridley turtles reveals Gabon hosts the largest rookery in the Atlantic. *Biological Conservation,* **190,** 14-22.

Montoya, F. & Drews, C. (2006) *Livelihoods, Community Well-Being, and Species Conservation. A Guide for Understanding, Evaluating and Improving the Links in the Context of Marine Turtle Programs*. WWF - Marine and Species Program for Latin America and the Caribbean, San Jose, Costa Rica.

Mortimer, J. A., von Brandis, R. G., Liljevik, A., Chapman, R. E. & Collie, J. (2011) Fall and Rise of Nesting Green Turtles (*Chelonia mydas*) at Aldabra Atoll, Seychelles: Positive Response to Four Decades of Protection (1968–2008). *Chelonian Conservation and Biology,* **10,** 165-176.

Mortimer, J.A., Meylan, A. & Donnelly, M. (2007) Whose turtles are they, anyway? *Molecular Ecology*, **16**, 17-18.

Myers, R. A., Barrowman, N. J., Hutchings, J. A. & Rosenberg, A. A. (1995) Population dynamics of exploited fish stocks at low population levels. *Science,* **269,** 1106-1108.

Nel, R. (2010) *Sea turtles of KwaZulu-Natal: Data report for the 2009/10 season*. Nelson Mandela Metropolitan University for Ezemvelo KwaZulu-Natal Wildlife, South Africa.

Nichols, W.J., Bird, K.E. & Garcia, S. (2000) Community-Based Research and its Application to Sea Turtle Conservation in Bahía Magdalena, BCS, Mexico. *Marine Turtle Newsletter*, **89**, 4-7.

Okemwa, G., Muthiga, N. & Mueni, E. (2005) *Proceedings of the Western Indian Ocean Region Marine Turtle Conservation Workshop*. September 16-17, 2004, Mombasa, Kenya. 26pp.

Pilcher, N.J. & Chaloupka, M. (2013) Using community-based monitoring to estimate demographic parameters for a remote nesting population of the Critically Endangered leatherback turtle. *Endangered Species Research*, **20**, 49-57.

Pusineri, C. & Quillard, M. (2008) Bycatch of Protected Megafauna in the Artisanal Coastal Fishery of Mayotte Island, Mozambique Channel. *Western Indian Ocean Journal of Marine Science*, **7**, 195-206.

Rakotonirina, B. P. (1987) *Les Tortues marines dans le Sud de Madagascar: Etude Bibliographique et enquêtes auprés des pêcheurs. Recherche sur la biométrie et l'alimentation de la tortue verte, Chelonia mydas Linnaeus*. Mémoire de DEA d'Océanographie Appliquée, Université de Toliara.

Rakotonirina, B. & Cooke, A. (1994) Sea turtles of Madagascar – their status, exploitation and conservation. *Oryx*, **28**, 51-61.

Rakotoson, L. & Tanner, K. (2006) Community-based governance of coastal zone and marine resources in Madagascar. *Ocean and Coastal Management,* **49,** 855–872.

Rasolofo, M. (2012) Country Presentation: Madagascar. In *Regional workshop and fourth meeting of the Western Indian Ocean Marine Turtle Task Force. 4-7 December 2012.* Port Elizabeth, South Africa.

Rees, A., Saad, A. & Jony, M. (2008) Discovery of a regionally important green turtle *Chelonia mydas* rookery in Syria. *Oryx*, **42**, 456–459.

Repoblikan'i Madagasikara (2013) *Réunion technique sur «les prises de mesures face au trafic de tortue marine à Madagascar». Note de presse. Mercredi 04 Décembre 2013*. Comite National de Gestion Integree de la Zone Cotiere et marine (CN-GIZC), Antananarivo.

Richardson, J. I., Hall, D. B., Mason, P. A., Andrews, K. M., Bjorkland, R., Cai, Y. & Bell, R. (2006) Eighteen years of saturation tagging data reveal a significant increase in nesting hawksbill sea turtles (*Eretmochelys imbricata*) on Long Island, Antigua. *Animal Conservation,* **9,** 302–307.

Richardson, P.B., Bruford, M.W., Calosso, M.C., Campbell, L.M., Clerveaux, W., Formia, A., Godley, B.J., Henderson, A.C., Mcclellan, K., Newman, S., Parsons, K., Pepper, M., Ranger, S., Silver, J.J., Slade, L. & Broderick, A.C. (2009) Marine Turtles in the Turks and Caicos Islands: Remnant Rookeries, Regionally Significant Foraging Stocks, and a Major Turtle Fishery. *Chelonian Conservation and Biology*, **8**, 192–207.

Rocliffe, S., Peabody, S., Samoilys, M. & Hawkins, J. P. (2014) Towards A Network of Locally Managed Marine Areas (LMMAs) in the Western Indian Ocean. *PLoS ONE,* **9,** 1-14.

Rosenbaum, H. C. (2003) Marine mammals. In *The natural history of Madagascar* (eds S. Goodman & J. Benstead), pp. 214-221. Chicago University Press, Chicago.

Sagar, J. (2001) *The ecology and conservation of sea turtles in the Nosy Be Islands, Madagascar*. Unpublished field mission report.

Schipper, J., Chnson, J.S., Chiozza, F., Cox, N.A., Hoffmann, M., Katariya, V., Lamoreux, J., Rodrigues, A.S.L., Stuart, S.N., Temple, H.J. & etc (2008) The status of the world's land and marine mammals: diversity, threat and knowledge. *Science*, **322**

Senko, J., Mancini, A., Seminoff, J.A. & Koch, V. (2014) Bycatch and directed harvest drive high green turtle mortality at Baja California Sur, Mexico. *Biological Conservation*, **169**, 24-30.

Senko, J., Schneller, A. J., Solis, J., Ollervides, F. & Nichols, W. J. (2011) People helping turtles, turtles helping people: Understanding resident attitudes towards sea turtle conservation and opportunities for enhanced community participation in Bahia Magdalena, Mexico. *Ocean and Coastal Management,* **54,** 148-157.

Shackeroff, J. & Campbell, L. (2007) Traditional Ecological Knowledge in Conservation Research: Problems and Prospects for their Constructive Engagement. *Conservation and Society,* **5,** 343-360.

Silver, J. & Campbell, L. (2005) Fisher participation in research: Dilemmas with the use of fisher knowledge. *Ocean and Coastal Management,* **48,** 721-741.

Smith, R. & Otterstrom, S. (2009) Engaging local communities in sea turtle conservation: strategies from Nicaragua. *The George Wright Forum*, **26**, 39-50.

Stokes, K. L., Fuller, W. J., Glen, F., Godley, B., Hodgson, D. J., Rhodes, K. A., Snape, R. T. E. & Broderick, A. (2014) Detecting green shoots of recovery: the importance of long-term individual-based monitoring of marine turtles. *Animal Conservation,* **17,** 593–602.

Stoner, A. W. & Ray-Culp, M. (2000) Evidence for Allee effects in an over-harvested marine gastropod: density-dependent mating and egg production. *Marine Ecology Progress Series,* **202,** 297–302.

Sullivan, B. J., Reid, T. A. & Bugoni, L. (2006) Seabird mortality on factory trawlers in the Falkland Islands and beyond. *Biological Conservation,* **131,** 495–504.

Troëng, S. & Rankin, E. (2005) Long-term conservation efforts contribute to positive green turtle *Chelonia mydas* nesting trend at Tortuguero, Costa Rica. *Biological Conservation,* **121,** 111–116.

Uychiaoco, A.J., Arceo, H.O., Green, S.J., De La Cruz, M.T., Gaite, P.A. & Alino, P.M. (2005) Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. *Biodiversity and Conservation*, **14**, 2775–2794.

Van Canneyt, O., Doremus, G., Laran, S., Ridous, V. & Watremez, P. (2010) *Distribution et abondance de la mégafaune marine dans le sud-ouest de l'océan Indien tropical*. Campagne REMMOA - Océan Indien. Universite de la Rochelle, La Rochelle.

Veitayaki, J. (1997) Traditional marine resource management practices used in the Pacific Islands: an agenda for change. *Ocean and Coastal Management,* **37,** 123-136.

Videira, E. J. S., Pereira, M. A. M. & Louro, C. M. M. (2011) *Monitoring, tagging and conservation of marine turtles in Mozambique: Annual report 2010/11*. Associação para Investigação Costeira e Marinha (AICM) and Centro Terra Viva – Estudos e Advocacia Ambiental (CTV), Maputo.

Walker, R. & Roberts, E. (2005) Notes on the status and incidental capture of marine turtles by the subsistence fishing communities of South West Madagascar. *Western Indian Ocean Journal of Marine Science*, **4**, 219-225.

Weber, S. B., Weber, N., Ellick, J., Avery, A., Frauenstein, R., Godley, B., Sim, J., Williams, N. & Broderick, A. (2014) Recovery of the South Atlantic's largest green turtle nesting population. *Biodiversity and Conservation,* **23,** 3005-3018.

Table 1. Number of days monitoring on each island each season and numbers of nests recorded, with interpolated (Int) numbers in brackets for the three islands monitored each season**.** No data indicates that no monitoring took place on that island that monitoring season.

Island (perimeter in kms)	**2011-2012**		**2012-2013**		**2013-2014**	
	Total days monitoring	**Count of nests (Int)**	**Total days monitoring**	**Count of nests (Int)**	**Total days monitoring**	**Count of nests (Int)**
Abohazo (2.08)	98	11 (14.9)	99	26 (41.1)	106	31 (42.9)
Andrano (2.13)	98	7 (4)	100	22 (26.3)	106	7 (8.7)
Dondosy (0.83)	102	2 (2)	99	2 (3.6)	106	4 (5.6)
Lava (2.46)	-	-	-	-	106	6
Mangily (1.35)	-	-	101	4	-	-
Mboro (1.16)	99	7	4	6	-	-
Total	**397**	**27 (27.9)**	**403**	**60 (80.9)**	**424**	**48 (63.1)**

Table 2. Pros and cons of community-based turtle nest monitoring

Positives	Negatives
Monitoring of extremely remote nesting sites easier than if using external researchers	Limited in level of data that can be collected as methods need to be kept relatively simple
Increases understanding and buy-in to marine turtle conservation	Monitoring not possible year round as nesting likely to be too low to warrant year round monitoring and community members need to return to fishing/alternative income-generating activities
Increases stakeholder engagement in development of other conservation or marine management programmes	Level of understanding of wider marine turtle conservation may not be as great
Engages community in turtle conservation in a region where tensions between community and authorities is high over illegal use of turtles	Maybe difficult for monitors to report illegal activities (eg. nest poaching) if performed by members of their own community
Monitoring costs reduced	
Easier for community members to discuss turtle conservation and wider issues between each other	

Figure 1. Map showing mean annual nesting numbers for islands monitored in the Barren Isles on the west coast of the island of Madagascar. Nosy Andrano, Nosy Abohazo and Nosy Dondosy were monitored each year, whilst Nosy Mboro was only monitored in 2011-12 and opportunistically in 2012-13. Nosy Mangily was monitored in 2012-13 only and Nosy Lava in 2013-14 only. Four islands were never monitored: Nosy Manandra, Nosy Maroantaly and Nosy Marify, and Nosy Ampasy. Nosy Manandra and Nosy Marify are sand banks and submerged at high tide during spring tides. Nosy Ampasy is only visible at low tide. The main town in the region, Maintirano, is shown and is where the community team members are based, and where most migrant fishers return to restock during periods on the islands.

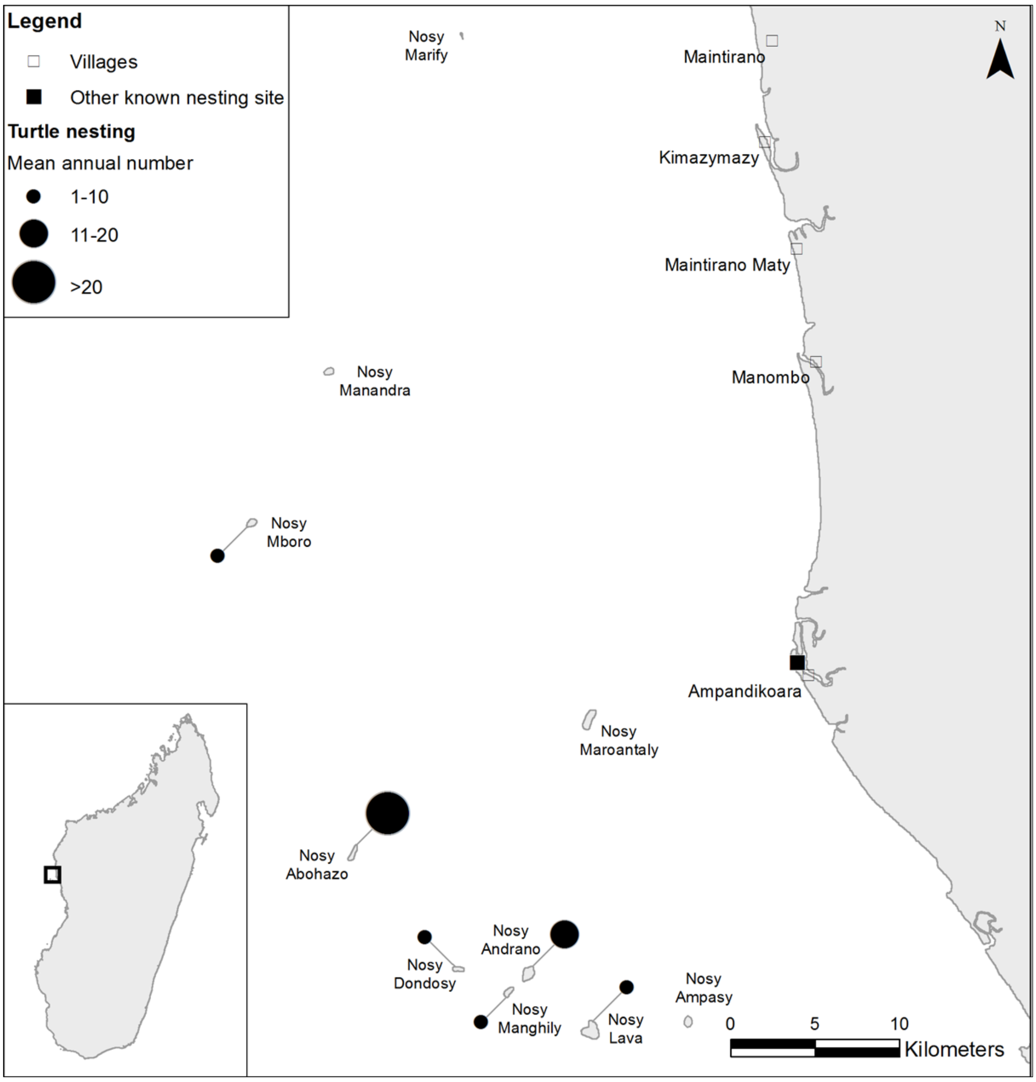

Figure 2. Map of current and historical known nesting sites in Madagascar. Historic nesting sites are shown as triangles sitting on the coastline. Current known nesting sites and sizes are shown as circles sitting off the coastline and represent annual number of nests. Asterisks highlight data based on body pit count. No attempt was made to extrapolate nesting given for a period less than a year. The location of one tagging site for tags retrieved by Blue Ventures is highlighted. Nest monitoring in this study is shown at site 13.

References for each site number are: 1 & 14: Metcalf et al., 2007; 2 & 17: Mealla, 2011; 3: Rasolofo, 2012, Elst et al., 2012 ; 4: CEDTM, 2001, Rasolofo, 2012; 5: Gladstone et al., 2003; 6: IOSEA, 2011, Elst et al., 2012; 7: G. Tovondrainy pers. comm.; 8 & 9: Walker & Roberts, 2005; 10: IOSEA, 2011; 11-13: Blue Ventures (this study); 15: Bourjea et al., 2006, Allison, 2008; 16: Sagar, 2011. Further information is available in Table S1 and S3.

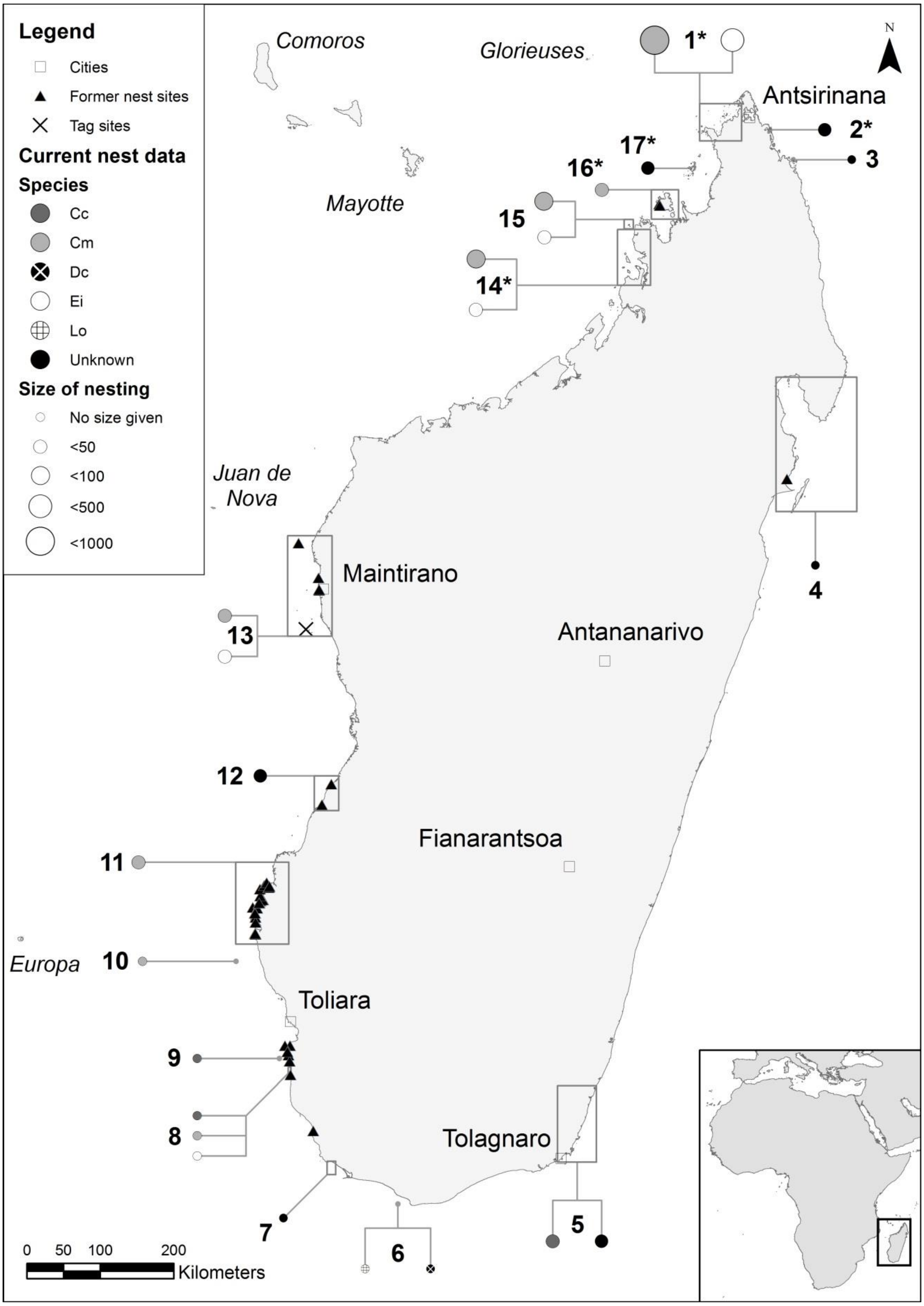
Legend
Cities
Former nest sites
Tag sites
Current nest data
Species
Cc
Cm
Dc
Ei
Lo
Unknown
Size of nesting
No size given
<50
<100
<500
<1000
Comoros
Glorieuses
Mayotte
Juan de Nova
Europa
Antsirinana
Maintirano
Antananarivo
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Figure 3. Map of current known nesting sites surrounding Madagascar. Current known nesting sites and sizes are shown as circles and represent annual number of nests. Asterisks highlight data based on (**) nesting turtles year^{-1} and (***) track counts. No attempt was made to extrapolate nesting given for a period less than a year. The origins of tags retrieved by Blue Ventures in Madagascar are highlighted.

References for each site number are: 18 & 30: Elst et al., 2012, Lauret-Stepler et al., 2007; 19: Bourjea, 2012 in Elst et al., 2012; 20: Bourjea et al., 2007; 21: Lauret-Stepler et al., 2010; 22: Elst et al., 2012, Lauret-Stepler et al., 2007; 23: Garnier et al., 2012; 24-28: Videira et al., 2011; 29: Nel, 2010; 31: Ciccione & Bourjea, 2006.

More information is available in Table S2.

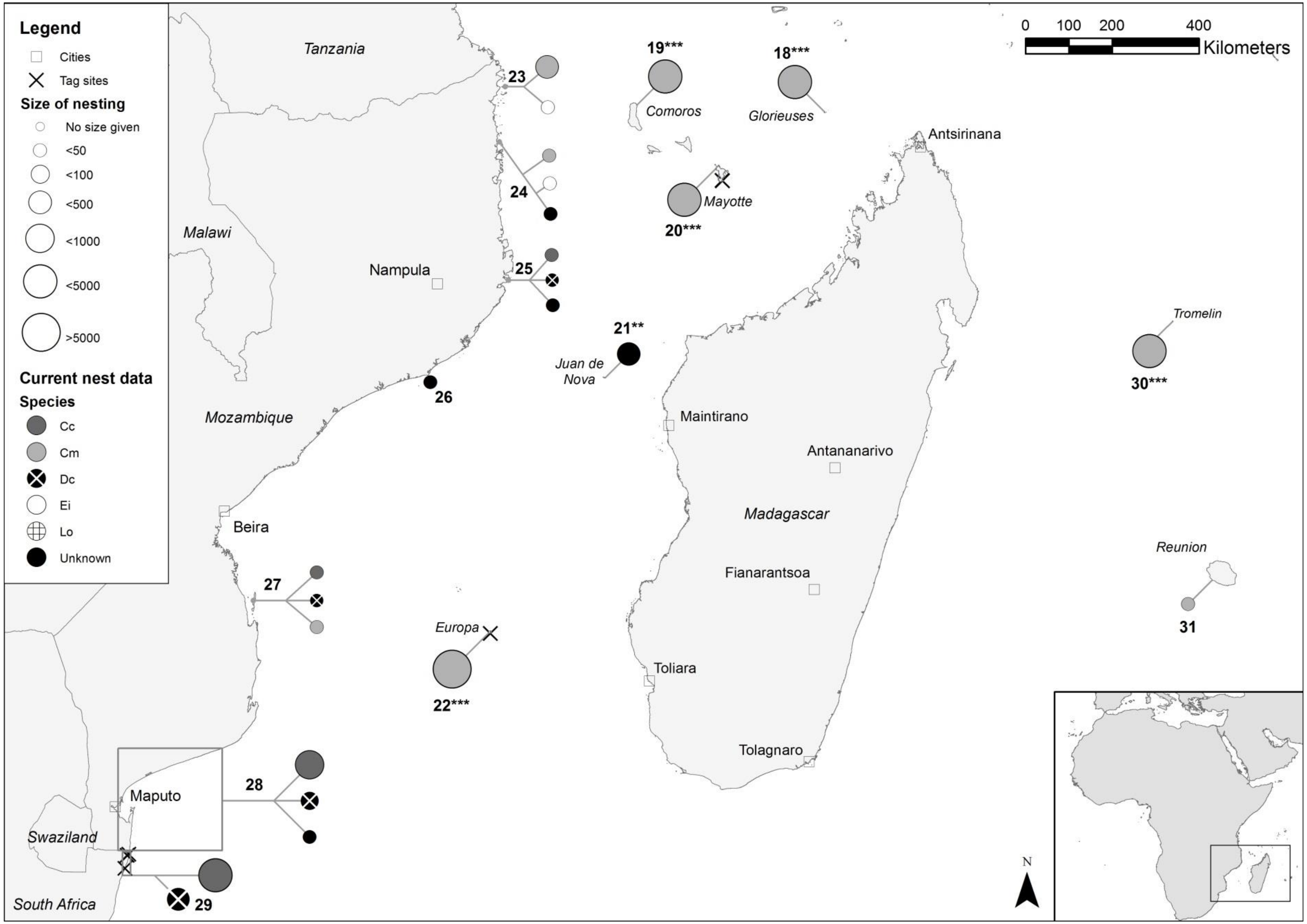
Legend
Cities
Tag sites
Size of nesting
No size given
<50
<100
<500
<1000
<5000
>5000
Current nest data
Species
Cc
Cm
Dc
Ei
Lo
Unknown
0
100
200
400
Kilometers
Tanzania
Malawi
Mozambique
Nampula
Beira
Maputo
Swaziland
South Africa
Comoros
Glorieuses
Mayotte
Juan de Nova
Europa
Madagascar
Antsirinana
Maintirano
Antananarivo
Fianarantsoa
Toliara
Tolagnaro
Tromelin
Reunion
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Figure 4. Green (a) and hawksbill (b) turtle nesting counts by half month over the 3 year survey period for the three islands monitored each season (Nosy Abohazo, Nosy Andrano, Nosy Dondosy). Data have been interpolated for the gaps in monitoring during the survey period. Dots indicate periods where there were no surveys between 26th May 2012 and 14th December 2012, and 19th May 2013 and 13th December 2013. Asterisks indicate incomplete 14 days of monitoring where data included have been interpolated.

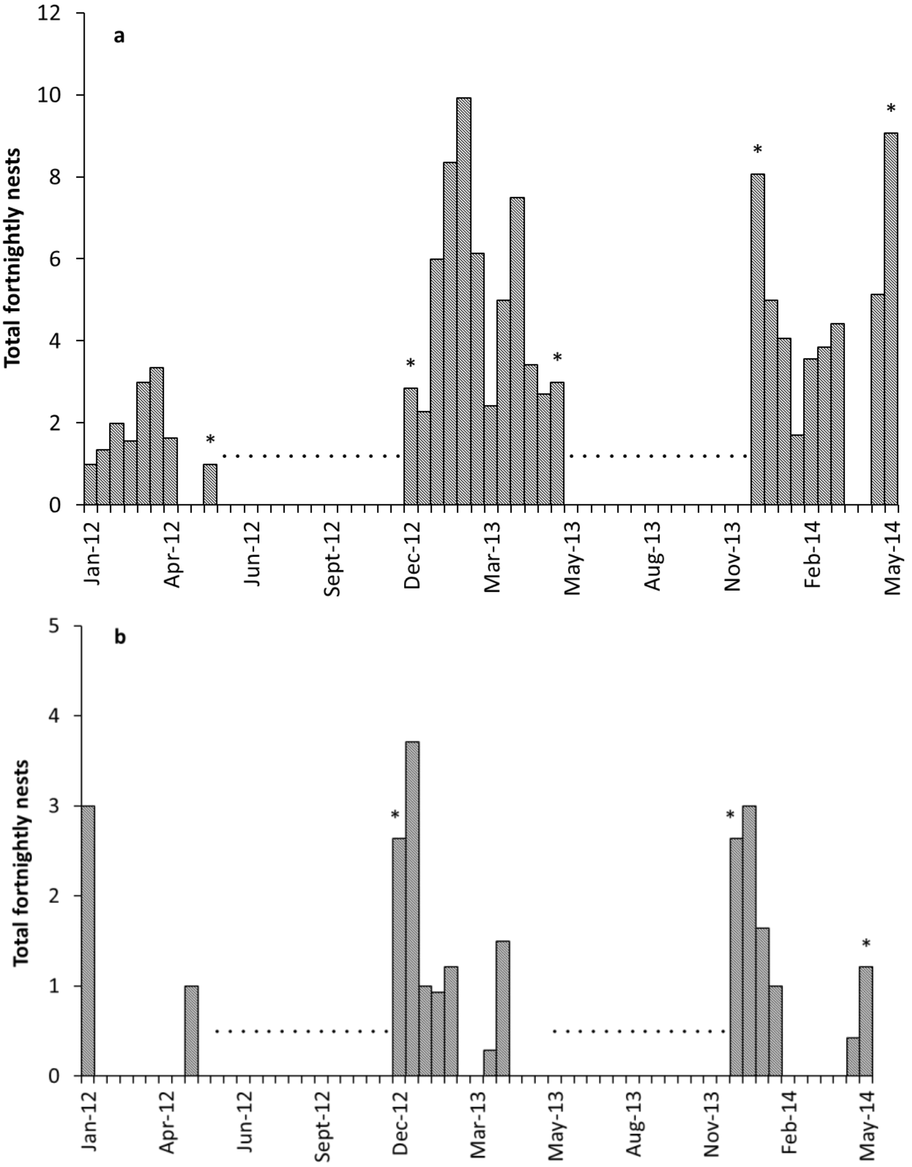

Figure S1: Estimated total nests for green (a, c, e) and hawksbill (b, d, f) turtles by month over the 3 year survey period for the three islands monitored each year (Nosy Abohazo, Nosy Andrano, Nosy Dondosy). Data have been interpolated for the gaps in monitoring during the survey period. There were no surveys between 26th May 2012 and 14th December 2012, and 19th May 2013 and 13th December 2013. ND = No monitoring occurred.

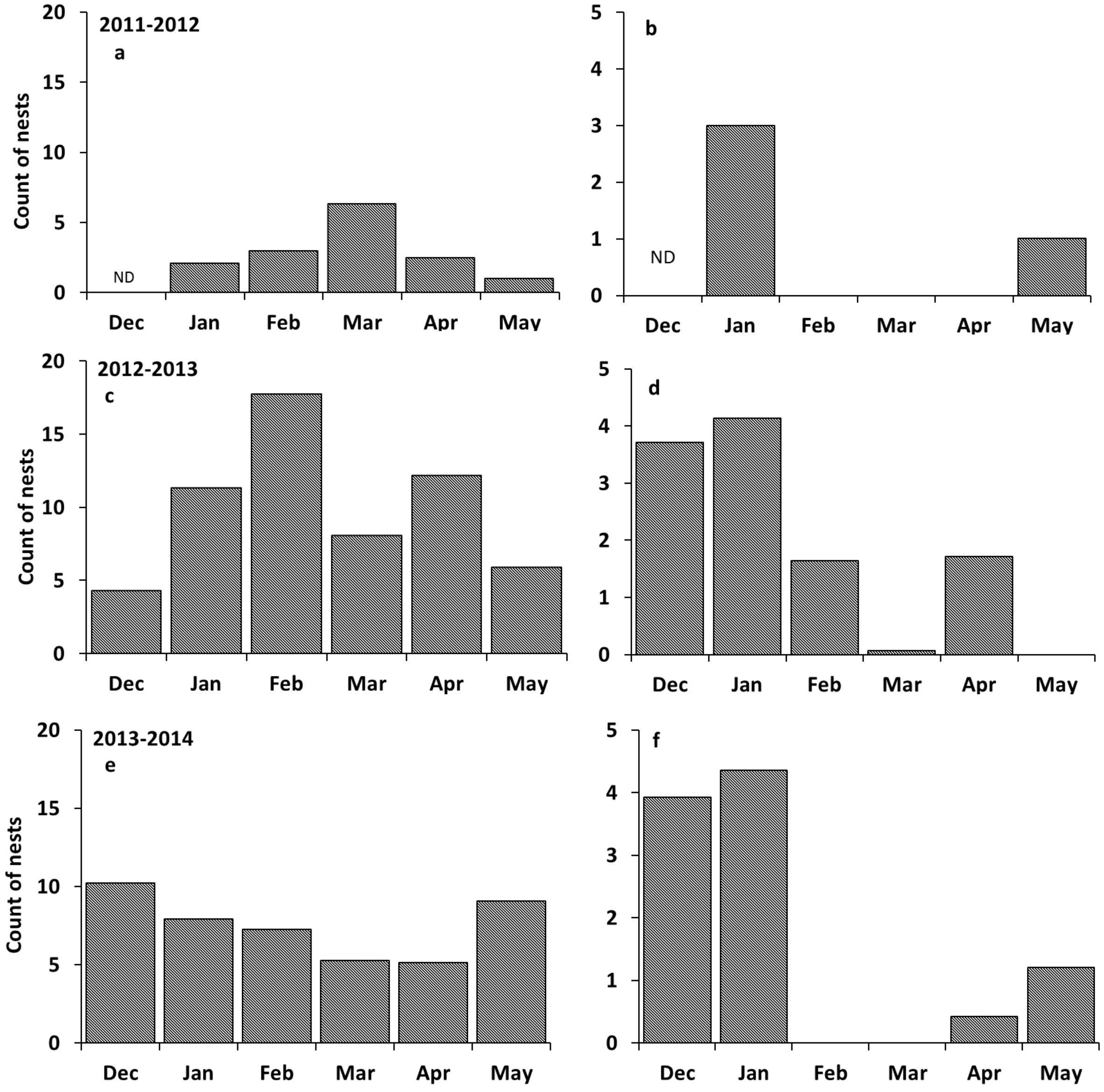

Table S1: Current nesting in Madagascar, its size, location and species. Species codes are Cm = green, Ei = hawksbill, Cc = loggerhead, Lo = olive ridley, Dc = leatherback, Un = Unknown. Site numbers refer to labels on Figure 2. References for each site number are: 1 & 14: Metcalf et al., 2007; 2 & 17: Mealla, 2011; 3: Rasolofo, 2012, Elst et al., 2012 ; 4: CEDTM, 2001, Rasolofo, 2012; 5: Gladstone et al., 2003; 6: IOSEA, 2011, Elst et al., 2012; 7: G. Tovondrainy pers. comm.; 8 & 9: Walker & Roberts, 2005; 10: IOSEA, 2011; 11-13: Blue Ventures (this study); 15: Bourjea et al., 2006, Allison, 2008; 16: Sagar, 2011.

Site number	Region	Species	Size of nesting	Year collected	Data type
1	Nosy Hara region	Cm	<1000	July-Dec 2000	Body pit count
		Ei	<500		
2	Ambolobozokely region	Un	<50	June 2011	Body pit count
3	Archipel (Barralums)	Un	No size given	Unknown	NA
4	Analandrafia Masoala Baie d'Antongil Ile Sainte Marie Manambato	Un	No size given	2011 Unknown Unknown Unknown Unknown	NA
5	96 km coastline north of Tolagnaro	Cc	<50	2001-2002	Number of nests
		Un	<50		
6	Parc National Marin Nosy Ve-Androka	Lo	No size given	2011	NA
		Dc			
7	Ambohibola-Nosy Manitse	Un	No size given	Unknown	NA
8	Beheloka-Besambay	Cm	No size given	2002	NA
		Ei			
		Cc			
9	Maromena	Cc	No size given	2002	NA
10	Salary Nord	Cm	No size given	2011	NA
11	Ankitambanga-Belavenoke	Cm	<50	2008	Number of nests
12	Lovobe-Antanimanimbo	Un	<50	2010-present	Number of nests
13	Barren Isles	Cm	<50	December-May (2011-2014	Number of nests
		Ei	<50		
14	Radama Islands region	Cm	<100	July-Dec 2000	Body pit count
		Ei	<50		
15	Nosy Iranja region	Cm	<100	2000-2008	Number of nests
		Ei	<50		
16	Nosy Be region	Cm	<50	Nov 2000-Jan 2001	Body pit count
17	Ankarana beach -	Un	<50	May 2011	Body pit count

	Nosy Mitsio				

Table S2. Records of regional known nesting sites in the islands surrounding Madagascar, Mozambique and northern South Africa. Species codes are Cm= green, Ei = hawksbill, Cc = loggerhead, Lo = olive ridley, Dc = leatherback, Un = Unknown.

References for each site number are: 18 & 30: Elst et al., 2012, Lauret-Stepler et al., 2007; 19: Bourjea pers. comm. in Elst et al., 2012; 20: Bourjea et al., 2007; 21: Lauret-Stepler et al., 2010; 22: Elst et al., 2012, Lauret-Stepler et al., 2007; 23 Garnier et al., 2012; 24-28: Videira et al., 2011; 29: Nel, 2010; 31: Ciccione & Bourjea, 2006.

*Data used for analyses started in 1992 due to gaps in full years of data collection.

Site number	**Country: Region**	**Species**	**Size of nesting**	**Year collected**	**Data type**
18	Glorieuses	Cm	<5000	1987-2006	Track counts
19	Comores: Moheli	Cm	<5000	Since 2000	Track counts
20	Mayotte: Moya & Saziley sites	Cm	<5000	Jan 1998-Dec 2005	Track counts
21	Juan de Nova	Un	<500	1987-2008*	Nesting turtles/year
22	Europa	Cm	>5000	1983-2006	Track counts
23	Mozambique: Vamizi	Cm	<500	Oct 2003-Sept 2007	Number of nests/year
		Ei	<50		
24	PN Quirimbas	Cm	<50	2010-2011	Number of nests/year
		Ei	<50		
		Un	<50		
25	São Sebastião	Cc	<50	2010-2011	Number of nests/year
		Dc	<50		
		Un	<50		
26	Primeiras e Segundas	Un	<50	2010-2011	Number of nests/year
27	PNA Bazaruto	Cc	<50	2010-2011	Number of nests/year
		Cm	<50		
		Dc	<50		
28	Mozambique: Ponta do Ouro to Macaneta	Cc	<1000	2010-2011	Number of nests/year
		Dc	<100		
		Un	<50		
29	South Africa	Cc	<5000	2009-2010	Number of nests/year
		Dc	<500		
30	Tromelin	Cm	<5000	1986-2006	Track counts
31	Réunion Island	Cm	<50	2004-2006	Number of nests/year

Table S3. Records of historical (defined as pre 2000) known nesting sites in Madagascar and possible species. Species codes are Cm = green, Ei = hawksbill, Cc = loggerhead, Lo = olive ridley, Dc = leatherback, Un = Unknown. No size of annual nesting was given for any of these nesting sites. References for each site number are: 4: CEDTM, 2001; 9: Walker & Roberts, 2005; 11-13: Blue Ventures (this study); 16: Sagar, 2011.

Site letter	Site – nearest village	Species	Last year of sighting	Year data collected
4	Pointe Mahela – Manompana	Un	<2001	2001
9	Itampolo	Cm	<2002	2002
	Anakao	Cm		
	Anakao	Ei		
	Anakao	Cc		
	Ambola	Cm		
	Andriangy	Cm		
	Nosy Ve	Cm		
	Befasy	Cm		
	Nosy Satrana	Cm		
11	Andoe avaratre - Nosy Andragnombala	Cm	1965	2011
	Antsotsomoroy – Andavadoaka	Ei	1991	
	Ampasilava – Belavenoke	Cm	1983	
	Agnorontane - Bevato South	Cc	1960	
	Anboapasy - Bevato North	Cc	1957	
	Antsatsamondika - Bevato South	Cc	1957	
	Depandempa - Bevato South	Cc	1965	
	Anboake avaratre - Bevato North	Cc	1966	
	Anboapasy Ovant - Bevato North	Cm	1966	
	Agnorontare Ovant - Bevato North	Cm	1966	
	Depandempa Ovant - Bevato North	Cm	1966	
	Amoronolagma - Nosy Be	Cm	1989	
	Nosy lava – Morombe	Cm	1971	
	Nosi-dolo – Morombe	Cm	1966	
	Andromona – Morombe	Cm	1971	
	Ananamdrome – Morombe	Cc	1985	
	Mandaviraty – Morombe	Cc	1974	
	Anopandikovia – Morombe	Cc	1975	
	Ampototry – Ampasilava	Cm	1990	
	Belalanda – Antsepoke	Cc	1995	
	Ankoapasy – Antsepoke	Cm	1983	
	Belalanda – Antsepoke	Cm	1980	
	Anbijeo - Nosy Ve	Cc	1984	
	Abelamera andrefa - Nosy Ve	Cm	1984	
	Ambatoloake - Bevato south	Cm	1962	
12	south of Begamela	Un	1980s	2013
	Ankaotelo			
13	Nosy Vao	Un	unknown	2013
	Near Manomba, Maintirano			
	Ampasimandoro beach, Maintirano			
	Ambalahonko, nr Maintirano			
16	West coast Nosy Be	Un	<2001	2001
	Djamanzar, Nosy Be		1990	

Chapter 5: Endangered, essential and exploited: how extant laws are not enough to protect marine megafauna in Madagascar

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Abstract

The decline of many marine megafauna species is of global concern; but many of these species, in particular marine mammals, have been afforded international and national protection and are the focus of conservation programmes. The existing national and international legislation are reviewed through which marine megavertebrates are afforded protection in Malagasy waters. The decline and protection of marine megafauna has followed a familiar pattern in Madagascar, with two main exceptions: marine turtles and elasmobranchs remain heavily exploited by national and international fishing fleets. The status of legislation governing both taxa is unclear and unknown by many working within the fisheries and marine sector. In Madagascar, marine turtles are fully protected from exploitation by national regulations in conjunction with a number of multilateral agreements. The numerous pieces of legislation that protect marine turtles are not coherent, regularly misunderstood and rarely enforced. Madagascar is taking steps to improve protection of marine turtles through the development of a national strategy, but it is recommended that the opportunity is also taken to improve understanding of current legislation and work more closely with local communities that consider turtle fishing a customary practice. Elasmobranchs however, receive minimal legal protection and only those listed under multilateral agreements are bound by any potential future management. Where legislation does exist to help manage elasmobranchs (eg. bycatch stipulations for foreign fishing vessels) it is incomplete and difficult to enforce. It is also recommended that Madagascar puts in place national elasmobranch legislation to help prevent their continued overfishing, especially in the face of increasing numbers of elasmobranch species on CITES and CMS. As such, both groups of species are rendered effectively unprotected and are in danger of

overexploitation. With the growth and proliferation of locally managed marine areas (LMMAs) in Madagascar the potential for local communities to increase protection and management of these species should be considered, especially with the limited capacity available to monitor and enforce legislation along such a vast coastline.

1. Introduction

Fisheries exploitation is not limited to finfish and invertebrate species but in many countries also includes megafauna [1-3]. Populations of large marine animals are estimated to have declined by 89% from their historical baseline, with rapid declines related to overexploitation [4]. The hunting of cetaceans, dugongs and marine turtles was historically much higher, although exploitation still continues today at reduced levels, due in part to an increase in protective legislation [5-7]. In contrast, the take of elasmobranchs has increased rapidly over the last half of the 20th century as the demand for shark fins from Asia became a major driver for the expansion of these fisheries [8,9], and are targeted by numerous small-scale and industrial fisheries [10-12].

Whales, dolphins, dugongs, elasmobranchs (including sawfish), and marine turtles are found in Madagascar’s waters, and include many species of global conservation concern [13]. Humpback whales (*Megaptera novaeangliae*), for example, are known to migrate along the east and west coasts of Madagascar, but they have not been historically targeted by fishers and currently receive full legal protection from exploitation by Decree 93-022, as do all marine mammals (Supplementary material Appendix S1). Dolphins appear to only be targeted opportunistically in a few isolated locations, primarily by *Vezo* fishers in southwest Madagascar [14,15]. Dugongs (*Dugong dugon*) and sawfish (family Pristidae) were historically targeted by fishers but are now thought to exist at such a low level in Madagascar that any exploitation is likely to be negligible [15]. Dugongs have been also protected since 1961 (Decree 61-096).

However, elasmobranchs (excluding sawfish) and marine turtles continue to be heavily exploited directly, through targeted fisheries and as bycatch in Madagascar's fisheries [16-18]. Both groups of species are of growing international concern and therefore included within a number of multilateral agreements (Convention on International Trade in Endangered Species of Wild Flora and Fauna, CITES; Convention of Migratory Species, CMS; Inter-American Convention for the Protection and Conservation Sea Turtles, IAC).The need, in particular, for better protection and management measures for elasmobranch species within multilateral agreements has been recognised [19]. Both groups of animals are considered keystone species, playing an important role in healthy ecosystem function, with declines in elasmobranch population numbers linked to decreases in overall health of coral reefs [20,21], and marine turtle populations important in the maintenance of seagrass beds and coral reefs [22].

Turtles receive significant protection nationally and internationally, with all seven species on the IUCN Red List [13] and the conservation of turtles and their habitats addressed in numerous multilateral agreements [23]. Only 42 countries permit any take of turtles as of 2013 [7]; but illegal take continues in many countries, often against a backdrop of a strong cultural fishery, or legislation that is not appropriate or implemented properly [24,25].

Elasmobranch fisheries, in particular shark, have historically had very few management measures globally, and despite anti-finning legislation in a number of regions, there has been no apparent decline in the shark catches or the fin trade [26], although a recent decrease in demand for shark fin has been reported in China

[27]. Growing concern on the status of elasmobranch populations has led to a recent increase in legislation and protection for elasmobranch species and populations. Five new shark species (of which *Sphyrna lewini, S. mokarran,* and *Carcharhinus longimanus* are extant in Madagascar's waters) and all *Manta* spp. (currently 2 species) entered CITES Appendix II in 2014 [28]. They joined three shark species (two of which are found in Madagascar's waters: *Rhincodon typus* and *Carcharodon carcharias*, added in 2003 and 2005 respectively) and the sawfish family (family Pristidae added in 2007) already listed. Further management and protection have also gained traction in recent years with new protected areas put in place for elasmobranchs and changes in government policies [29,30].

Both groups of species are exploited by the same groups of traditional and artisanal fishers along the majority of Madagascar's coastline [16-18,31]**,** and are important fisheries within Madagascar. The marine turtle fishery is also culturally important, with traditions linked to ancestor worship [32,33] whilst the elasmobranch (primarily sharks) fishery has been fuelled by the high prices for shark fins in comparison to other marine resources [34]. Exploitation of sharks has increased as fishing pressure has increased with population growth and ecosystem degradation [34,35]; whilst traditions associated with marine turtle fishing have been eroded, reducing traditional resource management [36]. Despite this, marine turtle landings appear to have remained at constant levels since the 1970s [16,32,33,37]. The level of shark fishing in Madagascar is unclear; national export figures for shark fin show a steady increase since the early 1980s, with peaks in the mid-1990s and mid-2000s [15,34,38]. However, these figures are only for national fishing and do not include any sharks taken by foreign fishing vessels, and discrepancies with import data are known (G. Cripps pers. comm.). Indeed, a recent World Bank study highlighted the ‘incoherent and ambiguous’ legal framework that currently governs Madagascar’s fisheries sector [39].

This paper aims to review past and current legislation in Madagascar relating to the protection and management of marine turtles and elasmobranch populations in face of current levels of exploitation and reports of declines, and presents recommendations for future management.

2. National legislation

2.1. *How legislation is implemented in Madagascar*

Legislation in Madagascar follows the French hierarchy of texts (Table 1). The constitution in Madagascar is the highest text and sets the principles governing the country (including the protection of the environment). The constitution can only be revised in cases declared urgent by the President of the Republic or by the Parliament (Articles 161-163) [40]. Revisions of the constitution have occurred eight times since 1960, often marked by a change in regime, with the last one in 2010 [41]. Any treaties or international conventions (eg. Ramsar, The United Nations Framework Convention on Climate Change, CITES) have an authority superior to the national law once ratified (Article 137) [40]. Laws and ordinances, that can only relate to national issues, are created by the parliament and government (eg. national fisheries or forestry); and decrees are then adopted by Ministries to provide details in order to implement the above laws (eg. setting up a list of protected species, penalties). If further details are required to govern specific aspects or topics at the national or regional level (eg. fishery closure dates), the adoption of orders by administrative authorities is required. In addition, within Madagascar, *Dina* (a community level agreement that rules behavior among those that have agreed to it, permitting and prohibiting activities including those related to natural resource management) can be legally recognised through validation via the courts, or as part of defined contractual management transfers and co-management of renewable natural resources [42] (see Section 2.5 for further information).

2.2. *Earliest texts*

The first national legislation on either group of species was in 1923 (Table 2; Supplementary material Appendix S1). Two pieces of legislation were passed to protect a number of known marine turtle nesting sites and to forbid the capture of nesting females (Table 2). These were one of the first legal tools that specifically addressed the protection of any marine animal or resource in Madagascar, but no records exist of penalties being awarded for offences to either order. The material within these texts is now outdated, yet has not been officially overruled by more recent legislation, nor has the content been renewed. All marine turtles species were officially classified as a protected species in 1988 (Decree 88-243) [43] and granted full protection, although misclassification of a freshwater species was also included (Supplementary material Appendix S1). However, no penalties were associated with Decree 88-243 and, in 2006, it was superseded by Decree 2006-400 [44] (Table 2; Section 2.3.1). There are no historical texts that relate to the legislation of elasmobranch fishing or protection despite being part of industrial and artisanal fisheries since the 1950s [34, 45].

2.3. Current national texts

2.3.1. Protection

All five species of marine turtle found in Madagascar's waters receive complete protection through a number of pieces of national legislation, whilst elasmobranchs receive no explicit protection within domestic legislation (Table 2). After Madagascar gained independence, on June 26th 1960, the first text to regulate the use of fauna in hunting and fishing was adopted (Ordinance 60-126) [46]. This text states that it is forbidden to catch or hunt any "protected species" and details fines and imprisonment terms for any offences (Table 2). However, the protected species were not detailed until 1988 (Decree 88-243) [43], and updated with Decree 2006-400 [44]. Decree 2006-400 had a number of purposes, one of which was to implement Ordinance 60-126 and renew the classification of protected species in Decree 88-243. In Decree 2006-400 it is clearly started that it is prohibited to hunt, catch or possess a species under category I, class I (Table 2; Supplementary material Appendix S1). All five species of marine turtle found in the Indian Ocean/Madagascar fall under category **I** “protected species” which are based on CITES lists and Ordinance 60-126. No elasmobranch species are listed within Decree 2006-400 (Supplementary material Appendix S1).

2.3.2. Fishing regulations

2.3.2.1. National regulations

Marine turtles should receive additional protection within fisheries regulations by Ordinance 93-022 of May 4th 1993 [47], and elaborated further by Decree 94-112 [48], which provides the general guiding principles for fisheries and aquaculture activities in Madagascar (Table 2). The ordinance states that it is forbidden to kill, injure or catch marine mammals and endangered species (Supplementary material Appendix S1), which would have been defined within implementing texts, yet these texts were not drawn up. However, marine turtles were protected in the decree of 1988 and later confirmed in category 1, class 1 of Decree 2006-400. As elasmobranchs are not mentioned in any implementing texts (decrees), they cannot currently claim protection under Ordinance 93-022 nor Decree 2006-400.

A draft Fishery Code, remodelling Ordinance 93-022, is in discussion at present. Within this new regulation, marine turtles are granted continued complete protection from capture. Elasmobranchs are still not mentioned and only those protected within other national legislation or international conventions would be covered. As of May 2015, no further updates were available on the timeline of the implementation of this new fishery code.

2.3.2.2. Export

As a fisheries product, elasmobranchs and their related products (such as fins and meat) can be exported, and are therefore governed by commercial export requirements (Table 3). Any elasmobranchs species listed under CITES must be exported in line with CITES regulations for Appendix II species. Export of turtle products is prohibited unless a CITES permit is given in line with regulations for Appendix I species. Further information on CITES and export regulations are provided in Section 2.4.1.

2.3.2.3. Bycatch

Elasmobranch bycatch is not addressed by any specific national legislation, despite the fact that Decree 94-112 (put in place to complete Ordinance 93-022) specifies that the state can manage and limit bycatch. However, fishing access agreements[1] with national or foreign fleets can mention sharks as a prohibited species, and if sharks must be landed with fins attached. This clause is subject to negotiation and is not always present in every agreement (M. Andriamahefazafy unpublished data). Among fishing operators under these agreements, the European Union (EU) has the largest fleet in Malagasy waters with its majority composed of longliners and secondly, purse seiners [49,50]. Although longliners have a higher percentage of

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[1] Fishing access agreements determine the conditions and modalities of fishing in national waters, agreed between the MRHP of Madagascar and fishing operators (Article 13 of Ordinance 93-022).

bycatch than purse seiners, purse seiners can land higher volumes of fish and therefore may catch more individual sharks [51]. In December 2012, Madagascar signed an agreement with the EU, which set a catch limit of 200 tonnes of whole sharks.year^{-1} as bycatch within the EU fleet that target tuna and associated species [52]. Under the agreement, it is forbidden for EU boats to land two families and five species of shark (Table 4). However, the agreement does not provide any details on the further consequences of any sharks landed as bycatch within, or exceeding, this allowance. It is only detailed that >200 tonnes will be considered an infraction, as well as fishing prohibited species; and only notes that regarding bycatch, the EU will comply with the Indian Ocean Tuna Commission (IOTC) recommendations, of which Madagascar is a contracting party [52,53]. In the most recent IOTC compliance report Madagascar was only found to fully comply with one (and partly comply to two) of the three resolutions related to shark bycatch [54]. Shark bycatch was also reported to have declined from 2010 to 2012 in Madagascar's most recent national report to the IOCT, accounting for ~12% of sampled national landings [55].

A new four year agreement was signed between Madagascar and the EU in June 2014, and ratified by the European Council and Parliament on 15th December 2014, replacing the one that expired on 31 December 2014 [56, 57]. The new agreement allows for an increase in shark bycatch to 250 tonnes.year^{-1} allocated to the European fleet for shark catches [56].

The threat of marine turtle bycatch within the national fishing fleet has been addressed through Decree 2003-1101 [58] which required the use of Turtle Excluder Devices (TEDs) and Bycatch Reducing Devices (BRDs) within industrial and small-scale shrimp trawlers (Table 2). The management of sea turtle bycatch is also addressed by Resolution 12/04 by the IOTC [59], and is regulated by Decree 12.666/2014 (Table 2). One accidental capture was reported in 2012, but there have been no specific studies [55].

2.3.3. Wider coastal management

As part of Madagascar's coastal management efforts and with the support of the Indian Ocean Commission (IOC), the country has adopted plans and strategies for integrated management of coastal and marine areas since 1997 [60]. These initiatives were endorsed with the adoption of Decree 2010-137 [61] (Integrated Management of Coastal Zones), which directs the preservation of coastal areas and marine resources (Table 2). Even though marine turtles and elasmobranchs are not specifically mentioned in the decree it does put an emphasis on the importance of the sustainable management and protection of marine resources.

2.4. International regulations

Madagascar has adopted several international and regional multilateral, environmental agreements (MEAs) that give protection to marine turtles and some elasmobranch species. Under the 2010 Malagasy Constitution, any treaties or conventions duly ratified, upon official publication, have an authority superior to the national law.

2.4.1. CITES

CITES was ratified in 1975 by Madagascar. Although CITES is legally binding for states that have ratified CITES it does not automatically become part, or take the place, of national laws. Parties must adopt their own domestic legislation to ensure that CITES is implemented at the national level [23]. Although CITES must be adopted through national legislation, it has no national remit and its requirements do not impact the domestic use of turtles [62].

CITES has been enacted into national legislation through two texts that transpose the requirements of CITES to domestic law: Law 2005-018 [63], 30 years after ratification, and Decree 2006-097 [64] that detailed the rules for the implementation of Law 2005-018, including establishing the management body and scientific authorities as required by CITES (Table 2, Supplementary material Appendix S1). Currently five sea turtle species and one elasmobranch family (pristidae: sawfish) found in Madagascar are listed in Appendix I of CITES and as such international trade in their products is banned, and only authorised in exceptional circumstances [65] (Table 5). Six elasmobranch species and one genus found in Madagascar are listed in Appendix II, which is for species that may be threatened with extinction unless trade is regulated more strictly [65] (Table 5).

2.4.2. CMS

In 1979, Madagascar ratified the Convention on Migratory Species (CMS), which aims to conserve migratory species throughout their range. Under the Convention, each state party is required to protect endangered species. CMS places all marine turtle species under Appendix I which lists endangered migratory species, as well as under Appendix II which includes migratory species that would benefit from international agreements under CMS (Table 5) [66]. Two elasmobranch species found in Madagascar are currently listed in Appendix I and five are listed in Appendix

II (Table 5) [66]. A further 21 species will be added following the 2014 Conference of Parties [67], including hammerhead, ray and manta species found in Madagascar.

Although CMS does not need to be enacted into national legislation, countries may need to ensure legislation is in place in order to meet certain requirements of particular articles within the convention. For example, Article III states “parties that are range states of migratory species listed in Appendix I shall prohibit the taking of animals belonging to such species” (Table 5).

However, Article III of CMS also accommodates “the needs of traditional subsistence users” but the term has not been defined within the CMS text [62]. Therefore whilst this would seemingly allow subsistence use of species to occur at some level, there is confusion in other countries where legal harvest of marine turtles occur; and whether these parties are satisfying their obligations in relation to this convention, as commercial trade of turtles can form part of traditional use of turtles [23].

The Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia Memorandum of Understanding (IOSEA MoU) was drawn up under the auspices of CMS, and signed by Madagascar in April 2003 [68]. This is a non-binding framework, initiated under CMS, through which States of the Indian Ocean and South-East Asia, as well as other concerned States and partners, collaborate to protect, conserve, replenish and recover marine turtles and their habitats. Improvements in Madagascar’s implementation and reporting under this MoU were noted in the 2014 meeting of signatory states, although only partial implementation was noted for the majority of programme activities [69]. As of May

2015, Madagascar was not a signatory to the CMS Memorandum on the Conservation of Migratory Sharks (effective since March 2010).

2.4.3. Nairobi Convention

Madagascar ratified the Nairobi Convention in 1998 [70], which was updated in 2010 to the *Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Western Indian Ocean*. The convention offers a regional legal framework and coordinates the efforts of the member states to plan and develop programmes that strengthen their capacity to protect, manage and develop their coastal and marine environment sustainability [71], and Article 11 concerns specially protected areas and promotes protection of fragile ecosystems. Madagascar has not yet ratified the 2010 convention [72, Jacquis Rasoanaina pers. comm.].

The convention also includes the *Protocol concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region,* which lists olive ridley, loggerhead and leatherback turtles in Annex II (species of wild fauna requiring special protection); green and hawksbill turtles in Annex III (harvestable species of wild fauna requiring protection); and all five in Annex IV (protected migratory species) (Table 5) [71]. No elasmobranch species are currently listed. Articles 4, 5 and 6 set out the guidelines for protection and management of species found in each Annex (Table 5). Article 12 also highlights that “protective measures take into account the traditional activities of their local populations in the areas to be protected”. Therefore under the Nairobi Convention, harvest of species in Annex III is permitted as long as it meets certain criteria (eg. the species are not in danger of extinction).

The Nairobi Convention provides clear guidelines on the obligations required by each member state. However the use of the phrase “where required” within the texts provides countries with the discretion that action need only be taken if considered proven [73].

2.5. Management at the local level

The *Dina* is a social code that is a community law within Madagascar, generally communicated through oral tradition but is also written down in some cases [74]. The *Dina* coexisted alongside modern law during colonisation but there was a recovery of traditional values after independence in 1960. At its simplest, the *Dina* are a set of customary rules based on a consensus within the community, and therefore the local population are bound to respect their content [75] but are legally defined as a “*collective agreement, freely adopted by the majority of the Community called ‘Fokonolona’ aged from eighteen years old, or as applicable, its designated representatives (…)”* [76]. In the late 1990s the Malagasy Government enacted legislation that integrated these customary legal practices with the governmental laws. In addition, Madagascar’s “*Programme Environnemental 2 (PE 2)*”, one of the three phases implementing the National Environmental Action Plan (NEAP), was underway and being used to promote community-based natural resource management. In 1996, the Malagasy Government, through the then Ministry of Environment and Forests, introduced the “Gestion Locale Sécurisée” (GELOSE), or secured local management, with Law 96-025 of 30th September 1996 [77], to transfer authority to communities for management of natural resources (for example forests, lakes and pastures). Under this transfer, local communities can set up *Dina* to regulate and govern the use of natural resources (Articles 49-52) (Supplementary material Appendix S1). Although used extensively for terrestrial and mangrove management (as mangroves are considered to be part of forests), it cannot be currently applied to the marine environment because there are no specific texts as yet that put in place the management transfer of marine resources. In addition, *Dina* themselves can be legally recognised outside of the GELOSE framework, and used to govern natural resources on the basis of the socio-economic need of the community under Law 2001-004 of 25th October 2001 [76]. For *Dina* to be recognised under Law 2001-004, they must be validated by a Malagasy court (Section 2, Articles 7-9) (Supplementary material Appendix S1) [78,79].

Over the decades *Dina* have been developed to manage terrestrial resources and have spread to local coastal and marine resource management [80,81]. Their success has been varied but has been greatest where aligned with community aspirations and developed through full participatory approaches, such as in the Velondriake Locally Managed Marine Area (LMMA) where they govern marine resource use [81]. *Dina* have facilitated the proliferation of “bottom-up” management of marine resources in Madagascar in recent years [82-84]; and there are now >64 LMMAs covering over 11,000 km^2 (Mihari LMMA network pers. comm.), greater than 2.6 times the area covered by Marine Protected Areas (MPAs) [85].

The content of the *Dina* cannot contradict national legislation, only enhance it or validate local customs [75,86]. Several *Dina* exist that mention protection of marine turtles, some of which act as a means to communicate national law, whilst others appear to contravene it (Table 6). Due to the high cultural value of the turtle fishery in

Madagascar, the success of the application of these *Dina* has had mixed results [16,36,80]. Whilst some may have increased awareness of national legislation, the likelihood of community enforcement of *Dina* articles related to turtles is likely to be extremely low.

3. Resulting cross-cutting issues

3.1. *Continued overexploitation*

Populations of both elasmobranchs and turtles continue to be heavily exploited in Madagascar [16,90]. The lack of national legislation is one of the drivers that has led to the decrease in coastal shark populations to the point where shark fishing is becoming increasingly unprofitable (G. Cripps pers. comm.). Foreign fishing vessels that have access to Madagascar's waters have licenses with variable bycatch stipulations that often have loose or no requirements to monitor bycatch, details of bycatch species nor limits (M. Andriamahefazafy unpublished data). Furthermore, reported landings demonstrate some foreign vessels are clearly targeting sharks in Madagascar's waters, with Spanish longliner vessels landing 152 MT of sharks compared to 13.98 MT of tuna in 2011 [91]. In 2011, a six month agreement was also granted to a Korean fishing company for experimental targeted shark fishing (M. Andriamahefazafy unpublished data). Illegal fishing in Madagascar's waters is also known [48], and there are reports of a substantial Asian long-line fleet of which 7.5% of bycatch are estimated to be shark species [92].

The continued illegal take of marine turtles has been of national attention [93]. Although traditional fishing for turtles for local consumption has continued at similar levels since the 1970s [16,32,33,37], there were reports in 2012 of targeted turtle fishing by collector-exporters in Mahajanga seemingly destined for international export [94]. There were also reports of plastron (ventral surface of the shell) trafficking in southwest Madagascar for export (WWF Madagascar, pers. comm.). To help reinforce current legislation and protection, a regional order for the Atsimo Andrefana region (southwest Madagascar) was issued on 16th October 2013 that highlighted crimes within current legislation and infractions related to products destined for export [95].

3.2. *Lack of adherence to legislation*

Where legislation is in place to protect these species it has often been difficult to implement. At the community level, *Dina* that include bans on marine turtle hunting often do so to stay in line with national legislation, but often with the knowledge they will not be enforced [81]; other *Dina* have been known to contradict or mention only part of national regulations which could cause further confusion [80,88].

Reports analysing Madagascar’s application of CITES from 2004 to 2007 highlight that the use of regulations has been partial or non-existent due to a lack of knowledge, corruption, lack of will and limited capacity [96-98]; and both national and international large-scale infractions have been reported [99,100]. Exports of protected species increased dramatically during the recent coup (2009-2014), in particular illegal logging and export of rosewood, and demonstrated a general decline in governance and respect for the rule of law [101-103]. Low national governance scores and corruption have been linked with reduced conservation success and population declines of protected species [104,105], although there are criticisms of such simplistic models [106,107]. Madagascar is taking steps to tackle illegal trade [108] but there are likely to be challenges in tracking the new Appendix II elasmobranch species and adhering to CITES requirements, and the new species added to CMS. Scalloped hammerheads (*S. lewini*), one of the species recently listed on Appendix II of CITES and Appendix II of CMS, are regularly landed within

Madagascar’s shark fisheries and are likely to be a significant part of current fin exports [18, F. Humber unpublished data].

4. Gaps and conflicts within legislation

There are numerous gaps and conflicts in current legislation in Madagascar that result in inadequate protection for marine turtles and elasmobranchs (Table 7).

4.1. Drafting of texts

There is often insufficient stakeholder input and consultation into drafting of texts which has led to a disconnect between those that have developed the legislation and those that are most affected by them or responsible for their implementation [109,110].

This disconnect has been highlighted in the lack of consultation and community engagement in the establishment of protected areas in Madagascar as part of the countries commitment in 2003 to triple its protected areas [111]. Furthermore, incongruities between texts and the feasibility of their implementation have been highlighted; within the application of GELOSE, Sarrasin (2009) emphasizes that communities are burdened with the majority of administrative requirements yet are the least well-placed to do so [112]. Effective consultation has been highlighted in the creation of a *Dina* to manage Madagascar's first LMMA, *Velondriake*, where participatory development has been key to engender local ownership [81]. Consultations with stakeholders have also been held at the national level in relation to the new national fishery strategy [113].

This is especially relevant to marine turtles where the fishery is considered part of local traditions, in particular in southwest Madagascar, and the national ban on turtle take is often unknown and/or ignored (Table 7) [16,80].

4.2. Implementation

The implementation of many legislative actions is compounded by issues of clarity, consistency between texts, and responsible bodies.

Despite the fact that many international conventions were ratified many years ago, their implementation at a national level has been insufficient. In particular authorities are unclear how to implement CITES at the national level for species thought to be targeted for international trade (Table 7) [114].

Inconsistencies currently lie between protected species listed in Decree 2006-400 and those that should be protected under CITES and CMS. For example, Decree 2006-400 only mentions one species of elasmobranch and is now out of date. Monitoring protected elasmobranch species is further complicated by the fact that sharks are currently classified and exported as a fishery product. In the past, there was no established link between the national CITES authorities (*Ministre de l'Environnement, de l'Ecologie, de la Mer et des Forêts*) and the Ministry of Fisheries (*Ministre des Ressources Halieutiques et de la Pêche*) but preliminary meetings have now been held after new species listings in 2013 (E. Robsomanitrandrasana, pers. comm.).

The proliferation of LMMAs in Madagascar has effectively initiated the first recognition of local management of marine resources, as management of coastal areas is designated to communities [81,85]. However, traditional migrations of fishers along the coast, and migration towards the coast from inland, has increased the potential for conflict to arise where established *Dina* are broken by migrant fishers [115,116].

4.3. Enforcement

Effective management of these species via current legislation is thwarted through a lack of enforcement, knowledge, communication and penalties across all levels of governance [36,80,90,114]. The 2009-2014 political crisis demonstrated the complex links between the impacts of political instability, poor governance in natural resource management and increased poverty [117].

A key recommendation from the 2011 IOSEA meeting in Madagascar was the need for a clear summary of existing legislation as discussions highlighted there was a clear gap in knowledge [114]. Anecdotal reports indicate that confusion still exists and communities still receive mixed messages from authorities concerning the legality of turtle meat consumption (114, F. Pichon pers. comm.). Irregular enforcement of legislation for marine turtles, due to a lack of capacity, willingness and/or priority, has undermined the status of the legislation itself and the authorities that enforce it. Whilst the continuation of turtle exploitation is generally ignored, incidences of erratic heavy-handed punishments (eg. arrests) of fishers, whilst others with more social status go unpunished, has led to growing distrust between authorities and communities in some regions (F. Pichon pers. comm.).

Enforcement of the bycatch allowance within EU fishing access agreements is weak due to insufficient capacity for monitoring and surveillance of Madagascar's EEZ [39,92] with only a small number of foreign vessels inspected in 2012 [55]. Within the

EU public access agreements bycatch was only stipulated for the first time in 2013, and there were no details regarding enforcement or penalties for exceeding the 200 tonne shark bycatch limits or if prohibited species were taken [52,53].

5. Recommendations

Table 8 summarises recommendations across the drafting, implementation and enforcement of legislation. Whilst legislation is currently in place to protect marine turtles from overexploitation, it is often ignored due to a lack of knowledge, will, resources for enforcement and the fact that it is incompatible with local customs. Elasmobranch species are poorly protected by current legislation and national level legislation should be put in place to help manage Madagascar’s elasmobranch fisheries, and promote recommended management measures [118,119]. However, Madagascar’s first shark sanctuary was created in north-east Madagascar in Antongil Bay, as part of a network of LMMAs aimed to grant coastal communities management rights for local fishery areas [120]. The no-take zone was officially implemented in December 2014 and shark fishing is prohibited through the bay’s management plan adopted by the MRHP [121] (Supplementary material Appendix S1). It is the first community level shark fisheries management measure established within a legal text in Madagascar.

The management and protection of elasmobranch fisheries has grown in recent years with many countries enacting unprecedented large-scale protection [30,122]. Country-wide and large-scale shark sanctuaries are now in place in many countries including the Cook Islands, Federated States of Micronesia, French Polynesia, Honduras, Maldives, Marshall Islands, Palau and Tokelau and commercial shark fishing is banned in the Bahamas and British Virgin Islands (UK) [123,124]; and loopholes closed within the EU so that sharks must now be landed with their fins “naturally attached” [125]. Marine turtle legislation has also been reviewed and updated in countries where it failed to protect the most vulnerable parts of life history to overexploitation, whilst ensuring that traditional customs can continue [126,127].

A national management plan for the conservation of marine turtles is currently being updated and has been validated at local workshops (M. Andriamahefazafy pers. obvs.). It could provide an opportunity for stakeholder consultations to improve knowledge and enforcement of current legislation, or to engage communities in how to manage subsistence use if it is assumed that capacity or will to curb this is minimal.

A current major loophole for potential large-scale overexploitation of elasmobranchs is through limited protection within distant water fleets fishing in Madagascar's waters (M. Andriamahefazafy unpublished data) and it is important that fishing access agreements promote minimising bycatch. Bycatch species should be clarified with limits given, and to minimise confusion, targeted species should also be clearly defined [128,129]. Some agreements refer to "migratory species" as those that can be targeted, leaving sharks a potential target species, whist contradicting the recommendations of the IOTC which Madagascar must uphold [130].

There is a growing network of local management associations and their supporting NGOs that are powerless to work with communities to reduce turtle and elasmobranch take within the current legal framework. Furthermore, engaging the private sector in conservation and resource management should be considered, as it has been successful where authorities may lack capacity or face challengers in terms of governance [104,131, T. Oliver unpublished results]. Financial restrictions also limit the ability for authorities to enforce legislation and the role of donors should be investigated.

6. Conclusion

Marine turtles and elasmobranchs remain Madagascar’s most valuable marine megafauna both economically, culturally and in terms of food security [17,132,133]; and are threatened by overfishing as direct take and as bycatch. The decline of both populations is fuelled in part by a lack of adequate legislation and poor enforcement in the face of increasing demand for marine resources from the international market, and continues to threaten their long term status. The almost complete lack of legislation for elasmobranch fisheries management, and the fact that legislation offering complete protection for marine turtles is ignored by fishers and traders, is difficult to enforce by authorities, and at odds with local customs, renders both groups of species “unprotected” in reality.

It is of national interest to protect both groups of species, not only in terms of their value as keystone species in maintaining healthy ecosystems, but also for cultural role that marine turtles play within *Vezo* culture, and as shark fins still provide an important source of income for many fishers [36, G. Cripps unpublished data]. The proliferation of LMMAs in Madagascar and the existence of a framework for decentralised management could be utilised to increase management across a country with such a vast coastline and limited monitoring and surveillance capacity. However, with no allowance for customary take of turtles, and with no national legislation for shark fisheries management, and the high value of shark fins, management by communities is likely to be limited. Incentives for local management are also reduced when high demand from illegal traffickers of marine turtles continues and industrial vessels take large numbers of sharks directly and as bycatch [92,93].

Globally, the status of elasmobranchs are becoming of greater concern as overfishing and large populations declines are reported [134-137]. Increases and recovery in turtle populations have been reported since widescale protection has been in place [138-141], and may result in the green turtle moving out of the threatened categories on the IUCN Red List. Madagascar’s marine resources are vital to the livelihoods of millions of people and a strong legislative framework with appropriate means of enforcement could help to significantly contribute to their protection.

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References

[1] Van Waerebeek K, Van Bressem M-F, Félix F, Alfaro-Shigueto J, García-Godos A, Chávez-Lisambart L, et al. Mortality of dolphins and porpoises in coastal fisheries off Peru and southern Ecuador. Biological Conservation. 1997;81:43–9.

[2] Kasuya T. Japanese whaling and other cetacean fisheries. Environmental Science and Pollution Research. 2007;14:39-48.

[3] Daley B, Griggs P, Marsh H. Exploiting Marine Wildlife in Queensland: The Commerical Dugong and Marine Turtle Fisheries, 1847–1969. Australian Economic History Review. 2008;48:227-65.

[4] Lotze HK, Worm B. Historical baselines for large marine animals. Trends in Ecology and Evolution. 2009;24:254-62.

[5] Marsh H, Gardner BR, Heinsohn GE. Present-day hunting and distribution of dugongs in the Wellesley Islands (Queensland): implications for conservation. Biological Conservation. 1981;19:255-67.

[6] Stevick PT, Allen J, Clapham PJ, Friday N, Katona SK, Larsen F, et al. North Atlantic humpback whale abundance and rate of increase four decades after protection from whaling. Marine Ecology Progress Series. 2003;258:263–73.

[7] Humber F, Godley B, Broderick A. So excellent a fishe: a global overview of legal marine turtle fisheries. Diversity and Distribution. 2014;20:579–90.

[8] FAO. FishStatJ - software for fishery statistical time series. Food and Agriculture Organization of the United Nations; 2011.

[9] Field IC, Meekan MG, Buckworth RC, Bradshaw CJA. Susceptibility of Sharks, Rays and Chimaeras to Global Extinction. Advances in Marine Biology. 2009a;56:275 - 363.

[10] Pierce SJ, Trerup M, Williams C, Tilley A, Marshall AD, Raba N. Shark fishing in Mozambique: A preliminary assessment of artisanal and semi-industrial fisheries. Maputo: Eyes on the Horizon, Maputo; 2008. p. 30.

[11] Blaber SJM, Dichmont CM, White W, Buckworth R, Sadiyah L, Iskandar B, et al. Elasmobranchs in southern Indonesian fisheries: the fisheries, the status of the stocks and management options. Reviews in Fish Biology and Fisheries. 2009;19:367–91.

[12] Cartamil D, Santana-Morales D, Escobedo-Olvera M, Kacev D, Castillo-Geniz L, Graham JB, et al. The artisanal elasmobranch fishery of the Pacific coast of Baja California, Mexico.Fisheries Research. 2011;108:393-403.

[13] IUCN. IUCN Red List of Threatened Animals. IUCN, Gland and Cambridge; 2014.

[14] Salvatore C, Andrianarivelo N, Razafindrakoto Y, Mendez M, Rosenbaum HC. Coastal dolphin hunting in the southwest of Madagascar: status of populations, human impacts and conservation actions. International Marine Conservation Congress. George Madison University, Fairfax, Virginia 2009.

[15] Cooke A, Lutjeharms J, Vasseur P. Marine and coastal ecosystems. In: Goodman S, Benstead J, editors. The natural history of Madagascar. Chicago: Chicago University Press; 2003. p. 179-209.

[16] Humber F, Godley BJ, Ramahery V, Broderick AC. Using community members to assess artisanal fisheries: the marine turtle fishery in Madagascar. Animal Conservation. 2011;14:175–85.

[17] Whitty TS, Davis P, Poonian CNS, Leandre I. Rapid assessment of marine megafauna capture, fishing effort, and socioeconomic and cultural drivers of artisanal fisheries in northern Madagascar. Proceedings of the World Small Scale Fisheries Congress, Bangkok, Thailand, 18-22 October 2010. p. 7.

[18] Robinson L, Sauer WHH. A first description of the artisanal shark fishery in northern Madagascar: implications for management. African Journal of Marine Science. 2013;35:9 - 15.

[19] CITES. CITES getting ready for sharks and rays. Convention on International Trade in Endangered Species of Wild Fauna and Flora; 2013.

[20] Myers RA, Worm B. Extinction, survival or recovery of large predatory fishes. Philosophical Transactions of the Royal Society B: Biological Sciences. 2005;360:13–20.

[21] Ruppert JLW, Travers MJ, Smith LL, Fortin M-J, Meekan MG. Caught in the Middle: Combined Impacts of Shark Removal and Coral Loss on the Fish Communities of Coral Reefs. PLoS ONE. 2013;8:e74648.

[22] Wilson EG, Miller KL, Allison D, Magliocca M. Why healthy oceans need sea turtles: the importance of sea turtles to marine ecosystems. Washington: Oceana; 2010. p. 20.

[23] TUKOT. Marine turtles and international law. An introduction to how the Environment Charter and selected Multilateral Environmental Agreements apply to marine turtles in the UK Overseas Territories. Available at <http://www.seaturtle.org/mtrg/projects/tukot/MEA_Guide.pdf>; 2005.

[24] Peckham SH, Maldonado-Diaz D, Koch V, Mancini A, Gaos A, Tinker MT, et al. High mortality of loggerhead turtles due to bycatch, human consumption and strandings at Baja California Sur, Mexico, 2003 to 2007. Endangered Species Research. 2008;5:171–83.

[25] Hitipeuw C, Windia Adnyana IB, Suprapti D, Andar R. Sea turtle trade in Indonesia: Current magnitude and new mode of operation. In: Tucker T, Belskis L, Panagopoulou A, Rees A, Frick M, Williams K, et al., editors. Proceedings of the

Thirty-Third Annual Symposium on Sea Turtle Biology and Conservation NOAA Technical Memorandum NOAA NMFS-SEFSC-645. Miami: National Marine Fisheries Service; 2013. p. 103-4.

[26] Worm B, Davis B, Kettemer L, Ward-Paige CA, Chapman D, Heithaus MR, et al. Global catches, exploitation rates, and rebuilding options for sharks. Marine Policy. 2013;40:194-204.

[27] Whitcraft S, Hofford A, Hilton P, O'Malley M, Jaiteh V, Knights P. Evidence of declines in shark fin demand, China. San Francisco: WildAid; 2014. p. 21.

[28] Mundy-Taylor V, Crook V. Into the deep: Implementing CITES measures for commercially-valuable sharks and manta rays. Report prepared for the European Commission. Cambridge: Traffic; 2013.

[29] Pew Charitable Trusts. Chinese Business Executives Lead the Way on Shark Conservation. Pew Charitable Trusts; 2014.

[30] Pew Charitable Trusts. Chuuk State Enacts Bill to Protect Sharks. Pew Charitable Trusts; 2014.

[31] Gladstone N, Andriantahina F, Soafiavy B. Azafady Project Fanomena – Marine Turtle Conservation and Research in Southeast Madagascar. Report on Activities and Findings in the 2001-2002 Nesting Season. London: Azafady; 2003. p. 75.

[32] Frazier J. Exploitation of Marine Turtles in the Indian Ocean. Human Ecology. 1980;8:329-70.

[33] Hughes GR. The status of sea turtles in South East Africa. I. Status, morphology and distributions. Durban: Oceanagraphic Reseach Institute; 1974a. p. 1-144.

[34] Cooke A. Survey of Elasmobranch fisheries and trade in Madagascar. In: Marshall NT, Barnett R, editors. The trade in shark and shark products in the Western Indian and Southeast Atlantic Oceans. Nairobi: Traffic East/Southern Africa; 1997. p. 101-30.

[35] McVean A, Walker R, Fanning E. The traditional shark fisheries of southwest Madagascar: A study in the Toliara region. Fisheries Research. 2006;82:280-9.

[36] Lilette V. Mixed results: conservation of the marine turtle and the red-tailed tropicbird by Vezo semi-nomadic fishers. Conservation and Society. 2006;4:262–86.

[37] Rakotonirina B, Cooke A. Sea turtles of Madagascar – their status, exploitation and conservation. Oryx. 1994;28:51-61.

[38] Ministère de la Pêche et des Ressources Halieutiques (MPRH). Captures de la pêche maritime par catégories administratives de pêcheries. 2011.

[39] Le Manach F. Valuation of fisheries resources in Madagascar. Draft report of the fisheries technical study prepared for The World Bank. Wealth Accounting and Ecosystem Services Valuation (WAVES) Global Partnership; 2012.

[40] Repoblikan’i Madagasikara. Constitution de la Quatrieme Republique [Consitution of the 4th Republic]. 2010. p. 28.

[41] Maury JP. République de Madagascar. Digithèque de matériaux juridiques et politiques. Université de Perpignan; 2006.

[42] Bérard M-H. Légitimité des normes environnementales dans la gestion locale de la forêt à Madagascar. Canadian journal of law and society. 2011;26:89-111.

[43] Repoblikan’i Madagasikara. Décret No. 88-243 modifiant les articles 1 et 2 du décret n° 62 096 du 16 février 1961 sur la liste d’espèces animaux protégées [Decree No. 88-243 amending Articles 1 and 2 of Decree 62 096 of 16th February 1961 on the list of protected animal species]. Ministere de l'Environnement. Antananarivo, Madagascar.15th June 1988.

[44] Repoblikan’i Madagasikara. Decret No. 2006-400 portant classement des espèces de faune sauvage [Decree No. 2006-400 on the classification of wildlife species]. Ministere de l'Environnement, des Eaux et Forêts. Antananarivo, Madagascar.13th June 2006.

[45] Fourmanoir P. Requins de la côte ouest de Madagascar. Mémoires de l'Institut Scientifique de Madagascar, Série F Océanographie. 1961;Tome IV:3-81.

[46] Repoblikan’i Madagasikara. Ordonnance No. 60-126 fixant le régime de la chasse, de la pêche et de la protection de la faune [Ordinance No. 60-126 establishing the regime of hunting, fishing and wildlife]. Ministere du Developpement Rural. Antananarivo, Madagascar. 3rd October 1960.

[47] Repoblikan’i Madagasikara. Ordonnance No. 93-022 portant réglementation de la pêche et de l'aquaculture [Ordinance No. 93-022 regulating fisheries and aquaculture]. Ministere de l’Elevage et des Ressources Halieutiques and Ministere d’Etat à l’Agriculture et au Développement Rural. Antananarivo, Madagascar. 4th May 1993.

[48] Repoblikan’i Madagasikara. Décret No. 94-112 Portant organisation générale des activités de pêche maritime [Decree No. 94-112 relating to the general organization of marine fishing activities]. Ministère d'Etat à l'Agriculture et au Développement Rural. Antananarivo, Madagascar. 18th February. 1994.

[49] Centre de Surveillances des Pêches (CSP). Rapport annuel d’activités année 2011. Antananarivo: Ministère de la Pêche et des Ressources Halieutiques; 2011. p. 76.

[50] Centre de Surveillances des Pêches (CSP). Rapport annuel d’activités année 2012. Antananarivo: Ministère de la Pêche et des Ressources Halieutiques; 2012. p. 75.

[51] COFREPECHE M, NFDS et POSEIDON. Évaluation rétrospective et prospective du protocole de l'accord de partenariat dans le secteur de la pêche entre l'Union européenne et la République de Madagascar. Contrat cadre MARE/2011/01 - Lot 3, contrat spécifique n° 10. Bruxelles; 2014. p. 175.

[52] European Union. Communiqué de presse, Partenariat Madagascar – Union Européenne. Available at <www.ambafrance-mada.org/IMG/pdf/Commission_mixte_accord_peche__27-09-12.pdf>; 2012 [accessed 21.09.14].

[53] European Union. Fisheries Partnership Agreement between the European Union and the Republic of Madagascar, Council Decision 2012/826/EU (OJ EU L361 of 31.12.2012).Available at <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2012.361.01.0011.01.ENG>; 2012. [accessed 21.09.14].

[54] IOTC Secretariat. Compliance Report (Madagascar). http://www.iotc.org/documents/compliance-report-madagascar. Victoria Mahé: Indian Ocean Tuna Commission (IOTC); 2014. p. 5.

[55] Rahombanjanahary DM, Rasolonjatovo H, Fanazava R, Ratsimanarisoa N. Rapport National de Madagascar destiné au Comité scientifique d la Commission des thons de l'océan Indien, 2013. Antananarivo: Ministere de la Peche et des Ressources Halieutiques; 2013. p. 30.

[56] European Union. Communiqué de presse conjoint, Partenariat dans le secteur de la pêche entre Madagascar et l'Union européenne. Available at: <http://eeas.europa.eu/delegations/madagascar/documents/press_corner/20140620_peche_fr.pdf>; 2014. [accessed 21.09.14].

[57] European Union. Fisheries Partnership Agreement between the European Union and the Republic of Madagascar, Council Decision 2014/929/EU.Available at: <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014D0929>; 2015. [accessed 18.01.15].

[58] Repoblikan'i Madagasikara. Décret No. 2003-1101 Modifiant certaines dispositions du décret n° 71-238 du 12 mai 1971, réglementant l'exercice de la pêche par chalutage, dans la mer territoriale malgache [Decree No. 2003-1101 Amending certain provisions of Decree No. 71-238 of 12 May 1971, regulating the practice of fishing trawling in Malagasy territorial sea]. Ministere de l'Agriculture, de l'Elevage et de la Pèche. Antananarivo, Madagascar. 25th November 2003.

[59] IOTC Secretariat. Resolution 12/04 on the conservation of marine turtles.<www.iotc.org/cmm/resolution-1204-conservation-marine-turtles>. Victoria Mahé: Indian Ocean Tuna Commission (IOTC); 2012. [accessed 12.10.14].

[60] Billé R, Mermet L. Integrated coastal management at the regional level: lessons from Toliary, Madagascar. Ocean and Coastal Management. 2002;45:41-58.

[61] Repoblikan'i Madagasikara. Décret No. 2010-137 Portant réglementation de la gestion intégrée des zones côtières et marines de Madagascar [Decree No. 2010-137 Regulating the integrated management of coastal and marine areas of Madagascar]. Antananarivo, Madagascar. 23rd March 2010.

[62] Richardson P, Broderick A, Campbell L, Godley B, Ranger S. Marine Turtle Fisheries in the UK Overseas Territories of the Caribbean: Domestic Legislation and the Requirements of Multilateral Agreements. Journal of International Wildlife Law and Policy. 2006;9:223–46.

[63] Repoblikan'i Madagasikara. Loi No. 2005-018 Sur le commerce international des espèces de faune et de flore sauvages [Law No. 2005-018 on International Trade of in Endangered Species of Wild Fauna and Flora]. Antananarivo, Madagascar. 17th October 2005.

[64] Repoblikan'i Madagasikara. Décret No. 2006-097 Fixant les modalités d'application de la loisur le commerce international des espèces de faune et de flore sauvages [Decree No. 2006-097 Fixing the procedures for implementing the Law on International Trade in Endangered Species of Wild Fauna and Flora]. Ministere de l'Environnement, des Eaux et Forêts. Antananarivo, Madagascar. 17th October. 2006.

[65] CITES. Convention on International Trade in Endangered Species of Wild Fauna and Flora. <www.cites.org>; 2014. [accessed 12.10.14].

[66] CMS. Convention on the Conservation of Migratory Species of Wild Animals. http://www.cms.int/; 2014. [accessed 04.12.14].

[67] Wildlife Conservation Society. New listing to protect 21 species of sharks and rays. <http://www.sciencedaily.com/releases/2014/11/141110110209.htm>. Science Daily; 2014. [accessed 12.11.14].

[68] Ministère de l'Environnement et des Forêts. Fifth national report to the Convention on Biological Diversity. Madagascar. Antananarivo: Ministry of Environment and Forests & UNEP; 2014. p. 221.

[69] IOSEA. Overview of IOSEA MoU Implementation. Synthesis of national reports as at 21 July 2014. MT-IOSEA/SS.7/Doc. 6 Agenda item 7a. Seventh Meeting of the Signatory States. Bonn: Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA); 2014. p. 33.

[70] Repoblikan'i Madagasikara. Loi No. 98-004. Autorisant la ratification de la convention pour la protection, la gestion et la mise en valeur du milieu marin et des zones côtières de la région de l'Afrique orientale et protocoles y relatifs (convection de Nairobi). [Law No. 98-004 Authorizing the ratification of the Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region and Related Protocols (Nairobi Convention)] 19th February 1998.

[71] United Nations Environment Program (UNEP). UNEP. Nairobi Convention. <http://www.unep.org/NairobiConvention/The_Convention/index.asp>; 2014. [accessed 13.08.14].

[72] Ministre de l’Environnement de l’Ecologie et des Forêts (MEEF). Convention de Nairobi. <http://www.ecologie.gov.mg/les-conventions-rattifiees-par-madagascar/convention-de-nairobi/>. Ministre de l’Environnement de l’Ecologie et des Forêts. [accessed 16.10.14].

[73] UNEP. Negotiating Language: Important Terms to Recognise & Understand. Guide for negotiators of Multilateral Environmental Agreements. Nairobi: UNEP Division of Environmental Law and Conventions; 2006.

[74] Rasamoelina H. Le vol de boeufs en pays Betsileo. Politique Africaine. 1991;52:22-30.

[75] Henkels D. A close up of Malagasy environmental law. Vermont Journal of Environmental Law. 2002;3.

[76] Repoblikan’i Madagasikara. Loi No. 2001-004 portant réglementation générale des Dina en matière de sécurité publique [Law no. 2001-004 on the general regulation of Dinas in terms of public security]. Antananarivo, Madagascar. 25th October. 2001

[77] Repoblikan'i Madagasikara. Loi no. 96-025 relative à la gestion locale des ressources naturelles renouvelables [Law No. 96-025 on the local management of renewable natural resources]. Antananarivo, Madagascar. 30th September 1996.

[78] Ignace R. L'insécurité rurale liée au vol de bœufs: quelques propositions de solution Taloha. 2010;19.

[79] Alliance Voahary Gasy (AVG). Ny Dina: Fitaoavana mahomby tena malagasy entin'ny fokonolona hanatsara ny fifampitondrana ary hitantanana maharitra ny harena voajanahary (Dina: an efficient Malagasy tool for communities to sustainable manage natural resources). Antananarivo: Alliance Voahary Gasy; 2011.

[80] Rakotoson L, Tanner K. Community-based governance of coastal zone and marine resources in Madagascar. Ocean and Coastal Management. 2006;49:855–72.

[81] Andriamalala G, Gardner CJ. L'utilisation du dina comme outil de gouvernance des ressources naturelles : leçons tirés de Velondriake, sud-ouest de Madagascar. Tropical Conservation Science. 2010;3:447-72.

[82] Harris A. Out of sight but no longer out of mind: a climate of change for marine conservation in Madagascar. Madagascar Conservation and Development. 2011;6:7-14.

[83] Ramandraiarivony T, Rakotonandrasana J. Gestion rationnelle des ressources naturelles renouvelables, pilier du développement durable. Rôle et place des transferts de gestion des ressources naturelles renouvelables dans les politiques forestières actuelles à Madagascar. Antananarivo: CIRAD; 2013.

[84] Ratsimbazafy R. L’océan au coeur de la Grande Île : Les aires marines protégées, un outil de développement durable pour Madagascar. Madagascar Conservation and Development. 2011;6:5-6.

[85] Rocliffe S, Peabody S, Samoilys M, Hawkins JP. Towards A Network of Locally Managed Marine Areas (LMMAs) in the Western Indian Ocean. PLoS ONE. 2014;9:1-14.

[86] Randrianarison M. Le vonodina. In: Randrianarison M, editor. La protection de la biodiversité à Madagascar: Les paiements pour services environnementaux (PSE): L’Harmattan; 2010. p. 59–61.

[87] Sagar J. The ecology and conservation of sea turtles in the Nosy Be Islands, Madagascar. Unpublished field mission report; 2001.

[88] Gibbons E. The Rufford Small Grants Foundation Final Report. FANO project. Available at: http://www.rufford.org/projects/emma_gibbons. 2013. [accessed 23.08.14].

[89] IOSEA. Indigenous communities of South-west Madagascar protect marine turtles. Available at: <http://www.ioseaturtles.org/feature_detail.php?id=403>. IOSEA; 2013. [accessed 23.09.14].

[90] Le Manach F, Gough C, Harris A, Humber F, Harper S, Zeller D. Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy. 2012;36:218-25.

[91] European Commission. Request for information on long-line catches in West Indian Ocean by Transparaentsea. Brussels 2013.

[92] Le Manach F, Gough C, Humber F, Harper S, Zeller D. Reconstruction of total marine fisheries catches for Madagascar (1950-2008). pp. 21-37. In: Harper, S. and Zeller, D. (eds.) Fisheries catch reconstructions: Islands, Part II. Fisheries Centre Research Reports 19(4). Fisheries Centre, University of British Columbia [ISSN1198-6727]. 2011.

[93] Repoblikan'i Madagasikara. Réunion technique sur «les prises de mesures face au trafic de tortue marine à Madagascar». Note de presse. Mercredi 04 Décembre 2013. Antananarivo: Comite National de Gestion Integree de la Zone Cotiere et marine (CN-GIZC); 2013.

[94] Rakotondrazafy AMNA, Andrianasolo RM. Evaluation préliminaire de la filière tortue marine dans la baie de Moramba, les zones de Marovasa Be et d'Anjajavy. Antananarivo: Cetamada; 2012.

[95] Repoblikan'i Madagasikara. Arrêté régional No. 2013-009/REG/ATSIMO ANDREFANA portant préservation des tortues menacées d'extinction dans la Région [Regional Decree No. 2013-009/REG/ATSIMO ANDREFANA relating to the preservation of endangered turtles in the region.] Ministere de la Decentralisation. Atsimo Andrefana, Madagascar. 16th October 2013.

[96] Reeve R. The CITES treaty and compliance: progress or jeopardy? Sustainable Development Programme BP 04/01. London: Chatham House; 2004. p.14.

[97] Reeve R. Wildlife trade, sanctions and compliance: lessons from the CITES regime. International Affairs. 2006;82:881-97.

[98] Anon. Evaluation de la politique nationale du commerce des espèces sauvages. Madagascar. Available at: <http://www.cites.org/sites/default/files/common/prog/policy/madagascar_fr.pdf>. CITES; 2007.

[99] Wildlifeextra. Lemurs slaughtered for bushmeat. Available at: <http://www.wildlifeextra.com/go/news/madagascar-lemurs536.html#cr>; 2009. [accessed 27.10.14].

[100] Durrell Wildlife Conservation Trust. Largest seizure of Critically Endangered ploughshare tortoises ever made. Available at: <http://www.durrell.org/latest/news/largest-seizure-of-

critically-endangered-ploughshare-tortoises-ever-made/>; 2013. [accessed 27.10.14].

[101] Global Witness, The Environmental Investigation Agency. Investigation into the illegal felling, transport and export of precious wood in Sava region, Madagascar. Global Witness &The Environmental Investigation Agency; 2009.

[102] Madonline. Exportation de bois précieux: Voahary Gasy porte plainte contre l'Etat. Available at: <http://www.madonline.com/article.php?article_id=03654&date=2014-10-26&lang=fr>; 2009. [accessed 26.10.14].

[103] Innes JL. Madagascar rosewood, illegal logging and the tropical timber trade. Madagascar Conservation and Development. 2010;5:6-10.

[104] Smith RJ, Muir RDJ, Walpole MJ, Balmford A, Leader-Williams N. Governance and the loss of biodiversity. Nature. 2003;426:67-70.

[105] Smith RJ, Walpole MJ. Should conservationists pay more attention to corruption? Oryx. 2005;39:251–6. Unpublished report.

[106] Katzner T. Corruption – a double-edged sword for conservation? A response to Smith & Walpole. Oryx. 2005;39:1-3.

[107] Barrett CB, Gibson CC, Hoffman B, McCubbins MD. The Complex Links between Governance and Biodiversity. Conservation Biology. 2006;20:1358–66.

[108] CITES. Malagasy President and CITES Secretary-General discuss actions to stem illegal timber trade in the margins of 69th UN General Assembly. Available at: <http://www.cites.org/eng/news/pr/2013/20130914_shark_ray.php>; 2014. [accessed 07.10.14].

[109] Norten M. The militarisation of marine resource conservation and law enforcement in the Western Cape, South Africa. Marine Policy. 2014;In press.

[110] Kashwan P. The politics of rights-based approaches in conservation. Land Use Policy. 2013;31.

[111] Corson C. From Rhetoric to Practice: How High-Profile Politics Impeded Community Consultation in Madagascar's New Protected Areas. Society and Natural Resources. 2012;25:336-51.

[112] Sarrasin B. La Gestion Locale Sécurisée (GELOSE) : L’expérience malgache de gestion décentralisée des ressources naturelles. Études Caribéennes. 2009;12.

[113] Madagate. Madagascar Pêche: validation du document de Stratégie nationale de bonne gouvernance des pêches maritimes. Available at: <http://www.madagate.com/editorial/communique/2437-madagascar-peche-

validation-du-document-de-strategie-nationale-de-bonne-gouvernance-des-peches-maritimes.html>; 2012. [accessed 03.05.15].

[114] Humber F, Hykle D. Report on the workshop for the adoption of a management and conservation plan for marine turtles in Madagascar. London: Blue Ventures Conservation and IOSEA; 2011. p. 56.

[115] Andriamalala G, Peabody S, Gardner CJ, Westerman K. Using social marketing to foster sustainable behaviour in traditional fishing communities of southwest Madagascar. Conservation Evidence. 2013;10:37–41.

[116] Pitt H. To Live with the Sea : Community-Based Management of Marine Resources in Southwest Madagascar; 2007.

[117] The World Bank. Madagascar: Measuring the Impact of the Political Crisis. The World Bank. Available at: <http://www.worldbank.org/en/news/feature/2013/06/05/madagascar-measuring-the-impact-of-the-political-crisis>; 2013. [accessed 28.04.15].

[118] FAO Marine Resources Service. Fisheries management. 1. Conservation and management of sharks. FAO Technical Guidelines for Responsible Fisheries No 4, Suppl 1 Rome, FAO 37p. 2000.

[119] Walker TI. Management measures. In: Musick JA, Bonfil R, editors. Management techniques for elasmobranch fisheries FAO Fisheries Technical Paper No 474. Rome: FAO; 2005. p. 216-42.

[120] Wildlife Conservation Society. Government of Madagascar Creates Country's First Shark Sanctuary. Available at:< http://press.wcs.org/NewsReleases/tabid/13614/articleType/ArticleView/articleId/6563/Government-of-Madagascar-Creates-Countrys-First-Shark-Sanctuary.aspx>; 2015. [accessed 17.02.15].

[121] Repoblikan'i Madagasikara. Arrêté Ministeriel No. 37.069/2014 portant définition du plan d'aménagement concerté des pêcheries de la baie d'Antongil [Ministerial Order No. 37.069/2014 relating to the definition of a collaborative fisheries management plan for Antongil Bay] Antananarivo, Madagascar. 18th December. 2014.

[122] Vince G. Maldives moves to protect its sharks. Available at: <http://news.bbc.co.uk/1/hi/sci/tech/7933662.stm>. BBC News; 2009. [accessed 27.08.14].

[123] CMS Sharks MoU. Shark Sanctuaries. Available at:<http://sharksmou.org/shark-sanctuaries>. Memorandum of Understanding on the Conservation of Migratory Sharks; 2014. [accessed 06.11.14].

[124] Humane Society International. National laws, multi-lateral agreements, regional and global regulations on shark protection and shark finning as of October 2014. Humane Society International; 2014.

[125] European Parliament.Available at: <http://www.europarl.europa.eu/news/en/news-room/content/20121122IPR56237/html/Parliament-closes-loopholes-in-shark-finning-ban>. Parliament closes loopholes in shark finning ban; 2012. [accessed 06.11.14].

[126] Campbell LM, Haalboom BJ, Trow J. Sustainability of community-based conservation: sea turtle egg harvesting in Ostional (Costa Rica) ten years later. Environmental Conservation. 2007;34:122-31.

[127] Stringell T, Calosso MC, Claydon JA, Clerveaux W, Godley B, Lockhart KJ, et al. Marine turtle harvest in a mixed small-scale fishery: evidence for revised management measures. Ocean and Coastal Management. 2013;82:34-42.

[128] Lewison RL, Crowder LB, Read AJ, Freeman SA. Understanding impacts of fisheries bycatch on marine megafauna. Trends in Ecology and Evolution. 2004;19:598-604.

[129] Kiszka J, Muir C, Poonian C, Cox TM, Amir OA, Bourjea J, et al. Marine Mammal Bycatch in the Southwest Indian Ocean: Review and Need for a Comprehensive Status Assessment. Western Indian Ocean Journal of Marine Science. 2009;7:119-36.

[130] European Union. Fisheries Partnership Agreement between the European Union and the Republic of Madagascar. Available at: <http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1421777222293&uri=CELEX:22007A1217(02)>; 2007. [accessed 21.09.14].

[131] Walpole MJ, Leader-Williams N. Masai Mara tourism reveals partnership benefits. Nature. 2001;413:771.

[132] Barnes-Mauthe M, Oleson KLL, Zafindrasilivonona B. The total economic value of small-scale fisheries with a characterization of post-landing trends: An application in Madagascar with global relevance. Fisheries Research. 2013;147:175-85.

[133] Tucker B, Tsimitamby, Humber F, Benbow S, Iida T. Foraging for Development: A Comparison of Food Insecurity, Production, and Risk among Farmers, Forest Foragers, and Marine Foragers in Southwestern Madagascar. Human Organization. 2010;69:375-86.

[134] Baum JK, Myers RA, Kehler DG, Worm B, Harley SJ, Doherty PA. Collapse and Conservation of Shark Populations in the Northwest Atlantic. Science. 2003;299:389-92.

[135] Cortés E, Brooks E, Apostolaki P, Brown CA. Stock Assessment of Dusky Shark in the U.S. Atlantic and Gulf of Mexico. Panama City, Florida: National Marine Fisheries Service, Southeast Fisheries Science Center; 2006.

[136] Ferretti F, Myers RA, Serena F, Lotze HK.Loss of Large Predatory Sharks from the Mediterranean Sea. Conservation Biology. 2008;22:952–64.

[137] Hayes C, Jiao Y, Cortés E. Stock assessment of Scalloped Hammerheads in the Western North Atlantic Ocean and Gulf of Mexico. North American Journal of Fisheries Management. 2009;29:1406-17.

[138] Broderick AC, Frauenstein R, Glen F, Hays GC, Jackson AL, Pelembe T, et al. Are green turtles globally endangered? Global Ecology and Biogeography. 2006;15:21-6.

[139] Chaloupka M, Bjorndal K, Balazs GH, Bolten AB, Ehrhart LM, Limpus CJ, et al. Encouraging outlook for recovery of a once severely exploited marine megaherbivore. Global Ecology and Biogeography. 2008;17:297–304.

[140] Kittinger JN, Van Houtan KS, McClenachan L, Lawrence AL. Using historical data to assess the biogeography of population recovery. Ecography. 2013;36:868–72.

[141] Stokes KL, Fuller WJ, Glen F, Godley B, Hodgson DJ, Rhodes KA, et al. Detecting green shoots of recovery: the importance of long-term individual-based monitoring of marine turtles. Animal Conservation. 2014.

Table 1. The hierarchy of legislation within Madagascar (with 1 being the highest).

Text (Official title in Madagascar)	**Set up by**	**Adopted by**	**Enforced by**
1. Constitution	Government	The Malagasy population	High Constitutional Court
2. Ratified International Conventions	Member states of the conventions	The President of the Republic after validation at the High Constitutional Court	Relevant governmental departments and national police (often outlined in implementing texts)
3. Laws and Ordinances (Loi et Ordonnance)	Government departments	Parliament/the President of the Republic if authorised by the parliament	National judicial authorities/Concerned government departments
4. Implementing Decrees (Décret)	Government departments	Government	National judicial authorities/ Concerned government departments
5. National and regional orders (Arrêté)	Government departments/Regional authorities	Governmental departments/Regional authorities	National and regional judicial authorities
6. *Dina*	Community	Community and validated by a judicial court	Community

Table 2: Past and current regulations that protect marine turtles in Madagascar. Relevant text from each piece of legislation is provided in Supplementary material Appendix S1.

Legislation	Area covered (Article)	Obligation	Status
Order of May 23, 1923	Nesting sites (Art. 1)	To set Nosy Anambo Nosy Iranja, Chesterfield, Trozona Nosy, Nosy Ve and Europa as protected nesting sites.	Outdated
	Penalties (Art. 2)	1 to 15 francs and imprisonment from 1 to 5 days.	
Order of October 23, 1923	Nesting turtles (Art. 1)	Prohibition of the capture of nesting turtles.	Outdated
	Minimum size (Art. 2)	Prohibition of the capture of turtles whose carapace is less than 0m50 in diameter.	
	Penalties (Art. 3)	1 to 15 francs and imprisonment from 1 to 5 days.	
Ordinance No. 60-126 on 3rd October 1960 establishing the regime of hunting, fishing and wildlife	Prohibited activities (Art. 2)	Prohibited activities: hunting and catching.	In application
	Penalties (Art. 45)	10 000 to 200 000 (no currency given) and/or .imprisonment from 1 month to 2 years and if necessary revocation of licenses permits and rights.	
Decree No. 88-243 on 15th June 1988 amending Decree 62-096 on the list of protected animal species	Full protection (Art. 1)	All species of sea turtle species except *Erymnochelys madagascariensis.*	Overruled
Ordinance No. 93-022 on 4th May 1993 setting up the regulations for fishing and aquaculture	Prohibited activities (referring to an implementing text that was not adopted) (Art. 9)	Prohibited activities: killing, injuring and catching of any endangered species.	In application (under remodelling)
Decree No. 94-112 on 18th February 1994 governing the general organisation of marine fishing activities	Regulation of bycatch in fishing licenses (Art 16.3.c and Art 27.c)	The Ministry of Fisheries determines the quantity of species allowed within fishing licenses including restrictions on bycatch allowed.	In application (under remodelling)
	Recording of bycatch (Art. 28)	Boat captains are required to record in a logbook the quantity of species, including bycatch species.	
Decree No. 2003-1101 on 25th November 2003 regulating the practice of trawling the Malagasy territorial sea	Turtle Excluder Device (Art. 12)	Shrimp trawlers on the west and east coast are required to have Turtle Excluder Devices.	In application
Law N ° 2005-018 on 17th October 2005 on International Trade in Endangered Species of Wild Fauna and Flora	Trade (Art. 29)	Prohibition of trade activities: the possession, buying, offer to buy, acquisition for commercial use for profit, exposure to public for commercial purposes, sale, detaining for sale, offering for sale or transporting for sale	In application
	Penalties (Art.30, 32, 33)	Six months to ten years imprisonment and a fine of 10 million Ariary to 200 million Ariary, or one of these penalties. The amount of the fine and the size of the penalty is doubled if the species are in Appendix I.	

Decree N ° 2006-097 on 31st January 2006 detailing the rules for the implementation of the law on International Trade in Endangered Species of Wild Fauna and Flora	International trade permits (Art. 6 & 11)	The management body after consultation of the scientific authorities issues permits, certificates and authorizations under the provisions of CITES and the national law on CITES, especially hunting, collection or capture permits.	In application
Decree No. 2006-400 on 13th June 2006 on the classification of wildlife species	Absolute protection (Art. 2)	Prohibited activities: hunting, capture and detention.	In application
Decree No. 2010-137 on 23rd March 2010 regulating the integrated management of coastal and marine areas of Madagascar	Caution duty (Art. 6e)	Each actor needs to avoid causing irreparable damage to the natural resources and risk to themselves and for future generations.	In application
	Sustainable management (Art.26)	Actors and local authorities to commit to rationally and sustainably manage coastal and marine resources.	
Order N°12.666/2014 on 28th March 2014 concerning the regulation of the conservation of marine turtles caught by fisheries (applicable to national longliners)	Care of injured marine turtles (Art. 2)	The boat captain shall take on board, where possible and as soon as possible, any caught/inanimate/inactive turtle during the fishing operation, and do everything possible to release it alive.	In application
	Bycatch equipment (Art. 3)	Boats must have onboard hook-cutters to facilitate quick handling and release of any marine turtles hooked or entangled. This should be done in compliance with the handling guidelines in the identification sheet of marine turtles of the IOTC.	
	Recording incidents (Art. 4)	The boat captain shall record in the fishing logbook all incidents involving marine turtles during fishing operations. This information should include the species, location of capture, conditions, actions taken on board and the place of release.	
Draft Fishery Code of 27th November 2014[a]	Harvest restriction (Art. 9)	It is prohibited at any time, any place, fishing, taking, detention and sale of all kinds of protected species including marine turtles.	Under adoption
2010 Constitution of Madagascar	Place of international treaties within national laws (Art, 137-4)	Treaties or agreements duly ratified, upon publication, have an authority superior to that of laws.	In application

[a] Draft text that is remodelling Ordinance 93-022 and is under adoption within the Ministère des Ressources Halieutiques et de la Pêche (MRHP) since 2011. At the time of writing of, this draft was not yet adopted.

Table 3: Documents required and controlled by national authorities for commercial export of all items (1-6) and marine resources (7).

Items	**Requirement**
1	A commercial invoice established by the exporting company
2	List of weight and packing of each package by the exporter
3	Value note given by the exporter
4	A certificate of origin according to different templates depending on the country of import – the templates are available at the chamber of commerce in Antananarivo
5	A transport letter from Transport Companies: "Lettre de Transport Aerien" for air shipments and "Bill of Lading" for maritime shipments
6	The customs declaration of export: Single Administrative Document (SAD)
7	The accreditation number and health certificate delivered by the sanitary authority (*Autorité sanitaire halieutique*) of the Ministère des Ressources Halieutiques et de la Pêche
8	A certificate or validation of export delivered by the Ministère des Ressources Halieutiques et de la Pêche

Table 4. Shark families and species forbidden as bycatch within the EU Fisheries Partnership Agreement [53]. IUCN Red List category: NT = Near Threatened, VU = Vulnerable, EN = Endangered.

Listed in agreement	**Species found in Madagascar**	**Common name (IUCN Red Listing)**
Family:		
Alopiidae	*Alopias pelagicus*	Pelagic thresher (VU)
	Alopias superciliosus	Bigeye Thresher Shark (VU)
	Alopias vulpinus	Common Thresher Shark (VU)
Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead (EN)
	Sphyrna mokarran	Great hammerhead (EN)
	Sphyrna zygaena	Smooth hammerhead (VU)
Species:	**Found in Madagascar**	
Cetorhinus maximus	No	Basking shark (VU)
Rhincodon typus	Yes	Whale shark (VU)
Carcharodon carcharias	Yes	Great white shark (VU)
Carcharhinus falciformis	Yes	Silky shark (NT)
Carcharhinus longimanus	Yes	Oceanic whitetip (VU)

Table 5. CITES and CMS restrictions and objectives by appendices; and marine turtle and elasmobranch species listings for those found in Madagascar waters [65,66]. Species are only placed in one Appendix for CITES dependent on their conservation status whilst can be placed within Appendix I and/or II for CMS.

Convention		**Appendix I**	**Appendix II**	**Appendix III**
CITES CITES is an international agreement that aims to regulate international trade in endangered species or those species that may become endangered if trade is not regulated and controlled.	**Restrictions**	Export permit: 1. a Scientific Authority of the State of export has advised that such export will not be detrimental to the survival of that species; 2. a Management Authority of the State of export is satisfied that: - the specimen was not obtained in contravention of the laws of that State for the protection of fauna and flora; - any living specimen will be so prepared and shipped as to minimize the risk of injury, damage to health or cruel treatment; - an import permit has been granted for the specimen.	Export permit: 1. a Scientific Authority of the State of export has advised that such export will not be detrimental to the survival of that species; 2. a Management Authority of the State of export is satisfied that: - the specimen was not obtained in contravention of the laws of that State for the protection of fauna and flora; and - any living specimen will be so prepared and shipped as to minimize the risk of injury, damage to health or cruel treatment.	Export permit: A Management Authority of the State of export is satisfied that : - the specimen was not obtained in contravention of the laws of that State for the protection of fauna and flora; and - any living specimen will be so prepared and shipped as to minimize the risk of injury, damage to health or cruel treatment. The import of any specimen shall require the prior presentation of a certificate of origin and, where the import is from a State which has included that species in Appendix III, an export permit.
	Species listed (Year)	Elasmobranchs: Pristidae (2007) All marine turtle species in Madagascar: *Chelonia mydas* (1981) *Eretmochelys imbricata* (1981) *Caretta caretta* (1981) *Lepidochelys olivacea* (1981) *Dermochelys coriacea* (1977)	Elasmobranchs: *Carcharodon carcharias* (2005) *Rhincodon typus* (2003) *Carcharhinus longimanus* (2014) *Sphyrna mokarran* (2014) *Sphyrna zygaena* (2014) *Sphyrna lewini* (2014) *Manta* spp. (2014)	None

CMS CMS aims to conserve migratory species throughout their range and parties should work unilaterally and cooperatively to provide strict protection for endangered migratory species (listed in Appendix I of the convention); concluding multilateral agreements (such as MoUs)(listed in Appendix II); and by undertaking co-operative research activities.	**Restrictions**	Parties that are Range States of a migratory species listed in Appendix I shall prohibit the taking of animals belonging to such species. Exceptions may be made to this prohibition only if: a) the taking is for scientific purposes; b) the taking is for the purpose of enhancing the propagation or survival of the affected species; c) the taking is to accommodate the needs of traditional subsistence users of such species; or d) extraordinary circumstances so require; provided that such exceptions are precise as to content and limited in space and time. Such taking should not operate to the disadvantage of the species.	Parties that are Range States of migratory species listed in Appendix II shall endeavour to conclude AGREEMENTS where these should benefit the species and should give priority to those species in an unfavourable conservation status.	NA - CMS only has two appendices.
	Species listed (Year)	Elasmobranchs: *Carcharodon carcharias* (2002) *Manta birostris* (2012) All marine turtle species in Madagascar: *Chelonia mydas* (1986) *Eretmochelys imbricata* (1986) *Caretta caretta* (1986) *Lepidochelys olivacea* (1986) *Dermochelys coriacea* (1983)	Elasmobranchs: *Carcharodon carcharias* (2002) *Isurus oxyrinchus* (2009) *Isurus paucus* (2009) *Manta birostris* (2012) *Rhincodon typus* (2000) All marine turtle species in Madagascar: *Chelonia mydas* (1983) *Eretmochelys imbricata* (1983) *Caretta caretta* (1983) *Lepidochelys olivacea* (1983) *Dermochelys coriacea* (1983)	NA - CMS only has two appendices.

		Annex II	Annex III	Annex IV
Nairobi Convention Protocol concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region.		Article 4: Species of wild fauna requiring special protection “The contracting parties shall take all appropriate measure to ensure the strictest protection of the endangered wild fauna species listed in Annex II. To this end, each Contracting Party **shall strictly regulate and where required, prohibit activities having adverse effects on the habitats** of such species. In particular, the following activities shall, where required, be prohibited with regard to such species: (a) All forms of capture, keeping or killing; (b) Damage to, or destruction of, critical habitats; (c) Disturbance of wild fauna, particularly during the period of breeding, rearing and hibernation; (d) Destruction or taking of eggs from the wild or keeping these eggs even if empty; (e) Possession of and internal trade in these animals, alive or dead, including stuffed animals and any readily recognizable part or derivative thereof.” Article 5: Harvestable species of wild fauna “The contracting parties shall take all appropriate measures to ensure the protection of the depleted or threatened wild fauna species listed in annex III **Any exploitation** of such wild fauna species **shall be regulated in order to restore and maintain the populations at optimum levels**. Each contracting party **shall develop, adopt and implement management plans for the exploitation** of such species which may include: (a) The prohibition of the use of all indiscriminate means of capture and killing and of the use of all means capable of causing local disappearance of, or serious disturbance to, population of a species; (b) Closed seasons and other procedures regulating exploitation; (c) The temporary or local prohibition of exploitation, as appropriate, in order to restore viable population levels; (d) The regulation, as appropriate, of sale, keeping for sale, transport for sale or offering for sale of live and dead wild animals; (e) These safeguards of breeding stocks of such species and their critical habitats in protected areas designated in accordance with article 8 of this Protocol; (f) Exploitation in captivity.” Article 6: Migratory species “The Contracting Parties shall, in addition to the measures specified in articles 3, 4, and 5, co-ordinate their efforts for the protection of migratory species listed in annex IV whose range extends into their territories. To this end, each Contracting Party shall ensure that, where appropriate, the closed seasons and other measures referred to in paragraph 2 of article 5 are also applied with regard to such migratory species.		
	Species listed (Year)	*Lepidochelys olivacea* (1985) *Caretta caretta* (1985) *Dermochelys coriacea* (1985)	*Chelonia mydas* (1985) *Eretmochelys imbricata* (1985)	*Chelonia mydas* (1985) *Eretmochelys imbricata* (1985) *Lepidochelys olivacea* (1985) *Caretta caretta* (1985) *Dermochelys coriacea* (1985)

Table 6. Details of articles with *Dina* for marine turtle protection in Madagascar

Location	Management body	Mechanism	Date	Article in *Dina*	Still in force	Comments	Ref
Nosy Ve, SW Madagascar	FIMIMANO (*Fikambanana Miarosy Mampandroso an'I Nosy Ve*, translated as the Association for the Protection and Development of Nosy Ve)	*Dina* under Law 96-025	1999	You are not allowed to hunt sea turtles during the months of October and November.	Unknown	Article in *Dina* actually contravenes national law (unknowingly as authors do not recognize this either) and although this follows the 1923 law, it suggests that you can hunt turtles outside of these months. Issues with *Dina* in general as fishers perceived regulations as a violation of their personal freedoms. *Dina* not necessarily valid under mechanism of Law 96-025, although validation methods not clear in text.	80
Velondriake LMMA, SW Madagascar	Velondriake Association	*Dina* validated by court	2006	It is forbidden to catch marine species under legal protection including marine turtles. The penalty for any infringement is MGA 20 000 plus confiscation of the catch.	Yes	The articles in the *Dina* are generally ignored, although there has been some movement to reduce turtle take for markets rather than subsistence use.	R. Samba pers. comm.
Nosy Sakatia, NW Madagascar	Unknown	Unknown	Unknown	Prohibits the killing of sea turtles; egg raiding prohibited.	Unknown	Punishments were given to those that killed a turtle successfully. Other beaches with high mortality not protected at time of report.	87
Bay of Ranobe, SW Madagascar	FI.MPA.MI.FA (Fikambanana MPaniriky Miaro ny	Unknown	Unknown (2013 likely)	Juvenile marine turtles under 70 cm curved carapace length (CCL) are protected.	Yes	Recent research suggests protection of larger individuals is better for population	88, 89

	Fano: The association of fishers for the protection of marine turtles based in the Bay of Ranobe)			Closed season, encompassing a four-month ban on turtle fishing from 1st December (not validated).		recovery Closed season *Dina*: articles contradict national legislation. It was submitted to Malagasy court of law for validation but advised that it was in conflict with national decrees.	
Villages near Tolagnaro, SE Madagascar	Villages themselves (Etapera, Elodrato, Antsotso, Ankaramany)	Unknown	2001-2002	Turtle harvest forbidden, including eggs.	Unknown	Level of adherence varied between villages from only one known transgression to multiple in other villages.	31

Table 7. Gaps and conflicts in current legislation relating to the protection of elasmobranchs and marine turtles.

Item	Issue	Elasmobranchs	Turtle
Drafting of texts	Insufficient legislation to protect populations/Lack of legislation.	✓	Legislation in place
	The majority of stakeholders that texts concern are not involved in the process of text development.	Lack of legislation	✓
	Existing national laws do not provide sufficient details of penalties if laws are broken.	✓	✓
	CITES is the only international convention that has a national implementation law to adapt the convention to the national context. The CMS and Nairobi Conventions do not have any texts to confer national implementation despite their importance.	✓	✓
Enforcement	Legislation is not well known across the different actors/stakeholders, leading to the legal framework being discarded.	Lack of legislation	✓
	Legislation is difficult to enforce (eg. shark bycatch laws for industrial vessels)	✓	✓
	Legislation is not communicated at the community level, the regional authorities, and the police. As a result, these laws are not enforced, or not enforced properly, at the national and local level.	NA	✓
	CITES procedures, from enforcement to permits, are not well known throughout Madagascar, and are difficult to enforce at the national/local level that could fuel international trade.	✓	✓
	There is no published or known history of penalization related to infractions that could provide tangible precedents for use by authorities. Various anecdotes of corruption regarding natural resource transactions in Madagascar have shown that corruption can represent a problem for the enforcement of texts.	Lack of legislation	✓
Implementation	Stipulations in international conventions are not always taken into account in national texts. For example, traditional allowance for marine turtles is permitted in CMS but prohibited at national level. Similarly, elasmobranch species in Appendix I of CMS should be protected but as yet are not under the Malagasy legislation.	NA	✓
	Due to the cultural value of marine turtles, legislation is currently incompatible with some local cultures in Madagascar.	NA	✓
	Greater migrations of fishermen are occurring along the coastal regions of	✓	✓

	Madagascar as a result of decreasing and degraded marine resources. Migrant communities are often in conflict with resident coastal communities where *Dina* are established.	

Table 8. Recommendations for the improvement in legislation for elasmobranchs and marine turtles in Madagascar.

Item	Issue
Development of texts	
Marine turtle	1. Scientific, socioeconomic and anthropological needs should be taken into account in upcoming texts, as well as considering local conventions “*Dina*” and regulations adopted in the Western Indian Ocean. 2. New implementation texts should be adopted based on the current management plan for marine turtles (as of February 2013).The management plan should include all recommendations and obligations from the CMS and the Nairobi Convention. 3. International vessels should also be required to comply with national legislation and use TEDs.
Elasmobranchs	1. Implement a national programme for conservation and management of shark stocks in relation to The International Plan of Action for Conservation and Management of Sharks (IPOA-SHARKS). 2. The protection and/or management of elasmobranchs should be mentioned in current fishery laws or implementing texts. 3. All species under CITES and CMS are added to the list of protected species in Madagascar. 4. As seven species are now under CITES protection, Malagasy authorities should consider export quotas for certain elasmobranch species.
Both	1. A national consultation of all concerned stakeholders should be undertaken before the adoption of new or updated texts. 2. Fines and sentences for offences should be included that directly relate to the legal obligations/prohibitions that are outlined in any existing or new text. 3. National implementing texts for the CMS and the Nairobi Convention should be set up and adopted to provide further protection to the species. 4. Bycatch stipulations within Fishing Access Agreements should be clarified with species and allowances detailed.
Enforcement	
Both	1. Legislation should be clearly understood by all stakeholders and needs to be published and shared to all national, regional and local authorities. Local communities should also be aware of all existing legislation to facilitate its implementation. A specific action should aim to clarify CITES procedures. 2. An analysis of the drivers of the international market

	could help to identify weaknesses in enforcement. 3. All stakeholders should be made aware of the main biological and ecological characteristics of marine turtles and elasmobranchs in order for appropriate legislation to not only be put in place but to be understood by all. 4. Awareness-raising should occur with stakeholders at local and national levels on the importance of marine turtles and elasmobranchs to promote the need for protection. 5. Texts currently in application that have penalties that can be easily applied by authorities to reprimand those caught with prohibited species should be promoted.
Implementation	
Marine turtle	1. To reduce the sale of marine turtles, the network of mayors/commune leaders could publish a local or regional text to prohibit their sale in accordance with national legislation.
Elasmobranchs	1. Increase in capacity for monitoring and surveillance of fishing vessels to observe elasmobranch landings and bycatch.
Both	1. The development and use of “*Dina*” should be encouraged and supported. 2. Information and educational awareness campaigns should be developed and/or strengthened. 3. Existing community management networks should be utilised for protection of marine turtles and elasmobranchs.

Appendix S1.Original articles of relevant legislation in Madagascar

Arrêté du 23 Mai 1923 (Order of May 23, 1923)

Article 1: Les ilots: Nosy Arambo ou ilot boisée (province de diego suarez), Nosy Iranja (province de Nosy Be), Chesterfield (province de Morondava), Nosy Trozona, Nosy Ve et Europa (Province de Tulear) sons mis en réserve pour la reproduction des tortues franches (Chelonia Midas) et des tortues a écailles ou carets (chelonian imbricate).

Article 2: Les contraventions aux dispositions du présent arrêtées seront punies d'une amende de 1 à 15 francs et d'un emprisonnement de 1 à 5 jours ou de l'une de ces deux peines seulement.

Arrêté du 24 Octobre 1923 (Order of October 23, 1923)

Article 1: Est interdite sur tous les rivages de Madagascar et dépendances la capture de tortues surprises en état de ponte ou procédant à l'enfouissement de leurs œufs.

Article 2: Est également interdite en tout temps la capture des tortues dont la carapace mesurée sous le plastron, n'atteint pas 0m50 de diamètre.

Article 3: Les contraventions aux dispositions du présent arrêtées seront punies d'une amende de 1 à 15 francs et d'un emprisonnement de 1 à 5 jours ou de l'une de ces deux peines seulement.

Ordonnance 60-126 fixant régime de la chasse, de la pêchée et de la protection de la faune (Ordinance 60-126 establishing the regime of hunting, fishing and wildlife)
Date: 3rdOctober 1960

Article 2: La chasse ou la capture, par quelque moyen que ce soit, des oiseaux ou autres animaux "protégés" sont interdites en tout temps.

Article 45: Les inscription aux prescriptions de la présente ordonnance seront punies d'une amende de 20 000 à 100 000 et d'un emprisonnement d'un mois a deux ans, ou de l'une de ces deux peines seulement, sans préjudice de dommages et intérêts et s'il y a lieu, du retrait du permis de chasse, de l'autorisation de chasse ou de pêche scientifique, de l'autorisation de chasse commerciale, ou de la réalisation de l'amodiation du droit de pêche ou de chasse.

Décret N°. 88-243 modifiant les articles 1 et 2 du décret n° 62 096 du 16 février 1961 sur la liste d'espèces animaux protégées (Decree No. 88-243 amending Articles 1 and 2 of Decree 62 096 of 16th February 1961 on the list of protected animal species)
Date: 15th June 1988

Article 1: Les animaux et les oiseaux énumérés ci-dessous sont protégés: (...) toutes les espèces d'espèces de tortues marines (...)

Ordonnance N°. 93-022 Portant règlementation de la pêche et de l'aquaculture (Ordinance 93-022 Regulating fishing and aquaculture)
Date: 4th May 1993

Article 9: Sauf autorisation spéciale délivrée à des fins notamment d'ordre scientifiques ou d'expérimentation technique par le Ministère chargé de la Pêche et de l'Aquaculture, il est expressément interdit de tuer, de blesser et de capturer des mammifères marins et d'autres espèces en danger telles que définies par voies règlementaires.

Décret N°. 94-112 du 18 Février 1994 portant organisation générale des activités de pêche maritime (Decree No. 94-112 On 18 February 1994 governing the general organization of marine fishing activities)
Date: 18th February 1994

Article 16:
3. Le Ministre chargé de la Péche et de l'Aquaculture peut, après avis de la Commission Interministérielle de la Pêche et de l'Aquaculture, inscrire dans une licence de pêche des conditions spéciales dont il juge le respect opportun, pouvant porter notamment sur:
c. les espèces et les quantités dont la capture est autorisée y compris, le cas échéant, des

restrictions, concernant les captures accessoires.

Article 27: Les renseignements sur le navire prévus à l'article 25 du présent décret doivent figurer sur la licence.

c. les espèces qui peuvent être pêchées, leur taille minimale ou leur poids minimal, ainsi que la proportion maximale d'espèces associées;

Article 28: Le capitaine du navire battant pavillon étranger autorisé tient un journal de pêche qui reprend pour chaque jour de pêche: la zone de capture, les conditions météorologiques, l'engin de pêche utilisé, le tonnage capturé par espèces principales, le tonnage des captures accessoires et toutes autres informations jugées utiles par les autorités malgaches.
Le journal est communiqué mensuellement à l'administration chargée des pêches.

Loi N°. 96-025 du 30 septembre 1996 relative à la gestion locale des ressources naturelles renouvelables (Law No. 96-025 on the local management of renewable natural resources)
Date: 30th September 1996

Art. 49: Les rapports entre les membres de la communauté de base sont réglés par voie de “Dina”.
Les “Dina” sont approuvés par les membres de la communauté de base selon les règles coutumières régissant la communauté.
Au cas où deux ou plusieurs communautés de base sont associées dans la gestion des ressources, le “Dina” applicable aux membres des communautés doit être approuvé par les membres de chaque groupe conformément aux règles propres régissant chaque communauté.

Art. 50: Les “Dina” ne peuvent comporter des mesures pouvant porter atteinte à l’intérêt général et à l’ordre public. Les prescriptions qu’ils contiennent doivent être conformes aux dispositions constitutionnelles, législatives et réglementaires en vigueur, ainsi qu’aux usages reconnus et non contestés dans la Commune rurale de rattachement.

Art. 51: Les “Dina” ne deviennent exécutoires qu'après visa du Maire de la Commune rurale de rattachement, valant autorisation d’application, sans préjudice du droit pour le représentant de l’Etat auprès de ladite collectivité de déférer devant les juridictions compétentes la décision ainsi prise qu’il estime entacher d'illégalité.

Art. 52: Les “Dina” régulièrement approuvés et visés par l'autorité compétente ont force de loi entre les membres de la communauté de base.
L’application du “Dina” est toutefois suspendue jusqu'à intervention d’une décision de justice, en tous cas de recours exercé contre la décision du Maire autorisant l’application du “Dina”.
La suspension d'exécution peut être limitée aux dispositions estimées illégales par le représentant de l’Etat, à moins qu’il ne soit allégué que ces dispositions forment un tout indissociable avec les autres dispositions du “Dina”. Le sursis d'exécution du “Dina” demandé par le représentant de l’Etat est porté devant la juridiction compétente qui statue selon la procédure d’urgence prévue dans les textes relatifs au fonctionnement des Collectivités territoriales décentralisées.

Loi N°. 2001-004 portant réglementation générale des Dina en matière de sécurité publique (Law No. 2001-004 for the general regulation of Dina in terms of public safety)
Date : 25th October 2001

Article 7: Le Dina ne devient exécutoire qu’ après son homologation par le Tribunal de l’ordre judiciaire compétent ou la Cour d’Appel ainsi que sa publication par voie d’affichage, de kabary ou par tout autre mode de publicité.

Article 8: Dans les trente (30) jours suivant son adoption, le projet de Dina est transmis par les soins du Maire au Conseil municipal ou communal.

Le Conseil dispose d’un délai de quinze (15) jours à compter de la date de réception du projet de Dina pour émettre son avis et le transmettre au représentant de l’Etat.

Le représentant de l’Etat fait parvenir le projet de Dina assorti de son avis au Tribunal de l’ordre judiciaire territorialement compétent dans un délai de quinze (15) jours. Ce délai court à compter de la date de réception du projet de Dina.

Le dossier doit être communiqué au Procureur de la République pour ses conclusions écrites dans le délai de trois jours de sa réception au Parquet.

Article 9: Le Président du Tribunal de Première Instance territorialement compétent
ou le juge qui le remplace doit statuer suivant la procédure de référé.

Le refus d'homologation d'un Dina doit être motivé.

Dans tous les cas, les décisions du Tribunal territorialement compétent sont susceptibles d'appel.

Le délai pour interjeter appel est de un mois.
L'appel est jugé par le Premier Président de la Cour d'Appel qui doit statuer dans un délai de quinze (15) jours.

La décision n'est pas susceptible de pourvoi en cassation.

Le Dina homologué est déposé dans chaque village et au bureau du Fokontany pour
être consulté par le public.

Décret N°. 2003-1101 Modifiant certaines dispositions du décret n° 71-238 du 12 mai1971, réglementant l'exercice de la pêche par chalutage, dans la mer territoriale malgache (Decree 2003-1101 Amending certain provisions of Decree No. 71-238 of 12 May 1971, regulating the practice of fishing trawling in Malagasy territorial sea)
Date: 25th November 2003

Article 12 (nouveau): (…) Pour les chaluts à crevettes opérant sur la côte Ouest de Madagascar, la mise en place d'un dispositif d'échappement des poissons d'accompagnement (By-catch Reducing Device ou BRD) est obligatoire. Il en est de même pour le dispositif d'échappement des tortues (Turtle Excluder Device ou TED), valable aussi bien sur la côte Ouest que sur la côte est.

Loi N°. 2005-018 Sur le commerce international des espèces de faune et de flore sauvages (Law 2005-018 on International Trade of in Endangered Species of Wild Fauna and Flora)
Date : 17th October 2005

Article 29: "Constituent des infractions au sens de la présente loi :(....)
4. Le transport de spécimens vers ou à partir de Madagascar, et le transit de spécimens via le territoire national sans le permis ou le certificat réglementaire délivré conformément aux dispositions de la présente loi et de ses textes d'application, et, dans le cas de l'exportation ou de la réexportation en provenance d'un pays tiers partie à la Convention, conformément aux dispositions de ladite Convention ou sans fournir la preuve de l'existence d'un tel permis ou certificat;

7. La possession, l'achat, l'offre d'achat, l'acquisition à des fins commerciales, l'utilisation dans un but lucratif, l'exposition au public à des fins commerciales, la vente, la détention pour la vente, la mise en vente et le transport pour la vente de tout spécimen appartenant à une espèce inscrite aux Annexes I, II, III ou relevant de l'annexe IV en violation des dispositions de la présente loi et de ses textes d'application;

Article 30 : (...) Ceux qui ont commis les infractions prévues aux paragraphes 1, 2, 3 et 4 de l'article 29 ci-dessus sont punis d'une peine de deux à dix ans d'emprisonnement et d'une amende de Ar 100 000 000 à Ar 200 000 000 ou de l'une de ces deux peines seulement (sans préjudices des autres sanctions pénales applicables).

Article 32: (...) Ceux qui ont commis les infractions prévues aux paragraphes 7 à 12 de l'article 29 ci-dessus sont punis d'une peine de six mois à deux ans d'emprisonnement et d'une amende de Ar 10.000.000 à Ar 50.000.000 ou de l'une de ces deux peines seulement.

Article 33 : Le montant de l'amende et le quantum de la peine d'amende sont doubles pour toute infraction liée à un spécimen appartenant à une espèce inscrite à l'Annexe I. La peine d'emprisonnement est toujours prononcée en cas de récidive."

Décret N°. 2006-097 fixant les modalités d'application de la loi sur le commerce international des espèces de faune et de flore sauvages (Decree 2006-097 of January 31st 2006 fixing the procedure for the application of the Law on International Trade in Endangered Species of Wild

Fauna and Flora)
Date: 31stJanuary 2006

Art. 6: L'Organe de Gestion est chargé notamment de :
1. Délivrer les permis, certificats et autorisations conformément aux dispositions de la CITES et la loi et en particulier les autorisations de chasse, de collecte ou de capture ;
2. Attacher à tout permis ou certificat toutes les conditions qu'il juge nécessaires ;
3. Coopérer avec les autres autorités compétentes pour l'application de la législation nationale concernant la conservation des espèces de faune et de flore sauvages ;
4. Tenir un registre de commerce international des spécimens et préparer un rapport annuel concernant ce commerce conformément à l'article VIII alinéa 7a de la CITES selon la périodicité usuelle ;
5. Décider de la destination finale des spécimens d'espèces de faune et de flore sauvages ;
6. Procéder ou faire procéder à l'étiquetage et marquage des spécimens d'espèces exportés ;
7. Décider de l'exportation à des fins non commerciales de spécimens d'espèces inscrites à l'annexe I et de l'exportation à des fins commerciales de spécimens d'espèces inscrites aux annexe II, III et IV de la loi n° 2005-018 du 17 octobre 2005 après consultation de l'Autorité Scientifique et les soumettre au besoin à un régime de quotas, fixé au cours du premier trimestre de l'année en cours ;
8. Désigner un ou plusieurs Centres de Sauvegarde pour les spécimens vivants saisis ou confisqués après consultation de l'Autorité Scientifique ;
9. Faire toute proposition destinée à mettre en application les normes et recommandations de la CITES ;
10. Accomplir toute autre tâche que lui confie le Ministre chargé des Eaux et Forêts dans le cadre de l'application de la CITES et de la loi n° 2005-018 du 17 octobre 2005 sur le commerce international des espèces de faune et de flore sauvages.

Art. 11: Les Autorités Scientifiques sont chargées de :
1. Vérifier l'aptitude du destinataire à conserver et traiter avec soin les spécimens vivants d'espèces inscrites à l'annexe I importés ou introduits ou faire ses recommandations à l'Organe de Gestion avant que celui-ci ne procède à l'instruction du dossier et à la délivrance des permis ou certificats ;
2. Indiquer à l'Organe de Gestion si les institutions scientifiques demandant leur enregistrement pour obtenir des étiquettes d'échange scientifique remplissent les conditions énoncées dans les résolutions des conférences des Parties, et se conforment à d'autres normes ou à toute exigence nationale plus stricte ;
3. Examiner toutes les demandes d'agrément ou autres soumises en vertu de l'article VII, paragraphes 4 ou 5 de la CITES concernant les espèces animales élevées en captivité ou végétales reproduites artificiellement, et indiquer à l'Organe de Gestion CITES si l'établissement en question répond aux critères de production, conformément à la Convention et aux résolutions pertinentes y afférentes ;
4. Réunir et analyser les informations sur les états biologique et écologique des espèces touchées par le commerce pour une meilleure connaissance de leur statut de conservation et pour proposer, le cas échéant, le changement de statut de ces espèces par amendement de annexes de la CITES ;
5. S'assurer que les conclusions et les avis de l'Autorité Scientifique du pays d'exportation concernant l'exportation des espèces inscrites aux annexes I ou II ou III de la loi n° 2005-018 du 17 octobre 2005 sont fondées sur une analyse scientifique des informations disponibles concernant l'état des populations, leur répartition géographique, leur tendance d'évolution (prélèvements, déperdition et autres facteurs biologiques et écologiques) et celles sur le commerce de l'espèce en question ;
6. Examiner les propositions d'amendement des annexes soumises par d'autres Parties et formuler des avis et recommandations pour permettre à Madagascar de se prononcer en toute connaissance de cause à la Conférence des Parties ;
7. Participer à la mise en œuvre des notifications CITES nécessitant un avis scientifique ;
8. Emettre des avis sur la délivrance des permis d'exportation ou des certificats d'introduction en provenance de la mer et particulièrement pour les espèces inscrites aux annexes I, II ou III de la n° 2005-018 du 17 octobre 2005, en indiquant dans quelle mesure ces transactions sont susceptibles de nuire à la survie des espèces en cause ;
9. Emettre des avis sur la délivrance des permis pour l'importation des spécimens d'espèces inscrites aux annexes II et III de la loi n° 2005-018 du 17 octobre 2005, en indiquant si les objectifs de l'importation sont susceptibles de nuire à la survie de ces espèces, et en se prononçant sur le risque éventuel induit par l'introduction d'espèces exotiques selon la loi sur la mise en comptabilité des investissements avec l'environnement (MECIE) ;

10. Surveiller de façon continue et appropriée la situation des espèces autochtones inscrites en annexe II de la loi n° 2005-018 du 17 octobre 2005 et les données relatives aux exportations et, si nécessaire, recommander les mesures correctives à prendre afin de conserver chaque espèce, dans toute son aire de répartition, à un niveau conforme à son rôle dans les écosystèmes et nettement supérieur à celui qui entraînerait son inscription à l'annexe I de la loi n° 2005-018 du 17 octobre 2005 ;
11. Conseiller d'Organe de Gestion sur la destination des spécimens saisis ou confisqués ;
12. Faire toute recommandation pertinente sur les mesures appropriées pour assurer la protection des espèces de faune et de flore sauvages ;
13. Effectuer toutes autres tâches à celles confiées par le Ministre chargé des Eaux et Forêts.

Décret N°. 2006-400 portant classement des espèces de faune sauvage (Decree No. 2006-400 on the classification of wildlife species)
Date: 13th June 2006

Article 2: Les espèces de faune sauvage relevant de la Catégorie I (espèces protégées) (…) Classe I bénéficient d'une protection absolue sur tout le territoire de la République Malgache et ne peuvent ni être chassées, ni capturées, ni être détenues sauf dans les cas prévus par l'article 20 de l'ordonnance n°60-126 du 3 octobre 1960 [chasse scientifique].

Décret N°. 2010-137 Portant réglementation de la gestion intégrée des zones côtières et marines de Madagascar (Decree 2010-137 Regulating the integrated management of coastal and marine areas of Madagascar)
Date : 23rd March 2010

Article 6: La gestion intégrée des zones côtières et marines doit s'appuyer sur le respect des principes suivants, tant lors de l'élaboration des plans et programmes qu'à l'occasion de l'adoption des décisions de toute nature dans l'espace couvert par le présent décret :
(…) e) La gestion des zones côtières et marines nécessite et implique un partage des responsabilités, prises individuellement et/ou collectivement. Chaque acteur, chaque groupe d'acteurs, chaque communauté ont un devoir de précaution vis à vis des ressources naturelles et de leur environnement, pour éviter de causer des risques et des dommages irréparables pour eux et pour les générations futures.

Article 26: Le Comité National de Gestion Intégrée des Zones Côtières assure le suivi et le contrôle de l'engagement dans les actions de production, de gestion et de mise en valeur durable des zones côtières. L'engagement est pris par les acteurs et les autorités locales en vue de:
- gérer rationnellement et durablement les ressources côtières et marines, au niveau local et régional, de manière participative, sécurisée et intégrée, afin de mieux responsabiliser les premiers bénéficiaires;
- reconnaître le droit inaliénable des citoyens d'accéder aux ressources ainsi que leur devoir de les protéger;

Arrêté N°. 12.666/2014 portant règlementation sur la conservation des tortues marines capturées par les pêcheries (Order N°12.666/2014 concerning the regulation of the conservation of marine turtles caught by fisheries)
Date : 28th March 2014

Article. 2: Le capitaine d'un navire de pêche doit amener à bord, dans les meilleurs délais, lorsque c'est possible, toute tortue marine capturée ou inanimée ou inactive durant l'opération de pêche, et fait tout ce qui est possible y compris la ranimer pour la remettre à l'eau vivante.

Article. 3: Les navires palangrier en activité doivent avoir à bord des coupes-lignes et des dégorgeoirs afin de faciliter la manipulation et la remise à l'eau rapide des tortues marines accrochées ou emmêlées. Le capitaine du navire et les marins à bord doivent pour ce faire suivre les directives de manipulation indiquées dans la fiche d'identification des tortues marines de la CTOI.

Article. 4: Le capitaine du navire est tenu d'enregistrer dans les journaux de pêche tous les incidents impliquant des tortues marines durant les opérations de pêche. Ces informations doivent inclure les espèces, le lieu de capture, les conditions, actions prises à bord et le lieu de la remise à l'eau.

Arrêté Ministeriel N°. 37.069/2014 portant définition du plan d'aménagement concerté des pêcheries de la baie d'Antongil (Ministerial Decree No. 37.069/2014 relating to the definition of a collaborative fisheries management plan for Antongil Bay)

Article 5: Activités de pêche admises dans la zone concernée par le Plan
A l'intérieur de la baie, en deçà de la ligne joignant le cap Masoala au cap Belone, seules sont autorisées la pêche traditionnelle, la pêche artisanale et la pêche industrielle crevettière. Toute autre activité de pêche industrielle ainsi que la pêche aux requins y sont interdites.

General Discussion

In this thesis I have presented a number of studies that provide further information on marine turtle and elasmobranch exploitation in Madagascar, and the status of the populations of both groups of animals. Participatory monitoring of marine turtle and elasmobranch landings presented in Chapters 1 and 3 highlight two active, small-scale fisheries (SSF) that are likely to provide significant income and protein for coastal communities in SW Madagascar. The level of (illegal) take of marine turtles in Madagascar (10,000 to 16,000 turtles.year^{-1}) is contextualised through the first estimation into the global take in legal turtle fisheries (estimated to be 42,000.year^{-1}) in Chapter 2. Populations of marine turtles in Madagascar are also threatened by direct take of nesting females and removal of eggs from nests. The results from the first participatory nest monitoring and protection programme in Madagascar in Chapter 4 demonstrates the importance of protecting the countries remaining small, scattered nesting sites, and that the presence of community monitors can help to protect nesting females and nests. The future of both groups of species is also dependent on their legal status. Chapter 5 reviews the current laws and legal mechanisms by which both marine turtles and elasmobranchs are afforded protection from national and international exploitation, and highlights that improvements to legislation are required to safeguard both groups from long-term overexploitation. In particular, elasmobranchs fisheries are poorly regulated and managed, with little legislation in place, as well as being targeted by numerous foreign, industrial vessels. Overall, the work presented not only provides up to date information on fisheries, policy and nesting for two of Madagascar’s megafauna populations, but also fills in important gaps in data for both groups of animals both in Madagascar and globally.

The characteristics of SSF are intrinsic within the two traditional (non-motorised) fisheries described in this thesis (elasmobranch and marine turtle), such as a wide use of gears and target species, highly labour intensive with low input capital, remote fishing and landings sites, and a relatively weak position in the value chain (Béné et al., 2007; Salas et al., 2007). The data provided in this thesis help to further fill in data gaps on important components of Madagascar’s fishing sector.

SSF were once perceived to also have low productivity and low yield rates, but this has been challenged by the growing body of studies that demonstrate the scale of production and significance of their contribution to national fisheries output and food security (Chuenpagdee et al., 2006; Béné et al., 2007; Jacquet et al., 2010). Much of this is achieved through the ability of SSF to evolve and adapt to rapidly changing conditions such as growing commercialisation and available technologies (FAO/FAO Advisory Committee, 2004; Béné et al., 2007).

There are many common problems that face the long-term sustainability of SSF including data deficiency, overexploitation, internal competition for resources and external conflict with industrial fleets (Salas et al., 2007). Despite their importance, efforts to address the lack of data within SSF have been minimal. A global estimate of SSF catches for 2000 was 21 million t year^{-1} for 12 million small-scale fishers (Chuenpagdee et al., 2006). The FAO reported a global catch of 64 million t in 2000, and depending on the amount of SSF data within the FAO data, SSF could contribute 25 to 33% to global catches (Chuenpagdee et al., 2006).

Ensuring that the significance of SSF is recognised within decisions related to fisheries policy and development means that better estimates on the number of people, the volume and contribution to livelihoods are required. A recent estimate for Madagascar suggested that between 1950 and 2008, total catch was twice that officially reported, with SSF the largest component of domestic fisheries (Le Manach et al., 2012). The study also highlighted that SSF had increased during the period but could start to decline by the early 2020s if the current rate of exploitation continued, with serious consequences for food insecurity (Le Manach et al., 2012). Over 70% of the population of Madagascar live below the national poverty threshold and 55.8% live below the minimum level of dietary energy (NFPA et al., 2014).

Although landings data and extrapolations did not show a decline in marine turtle and shark fisheries production, reports by fishers within this thesis, and previous studies within Madagascar, regularly cite severe declines in elasmobranch and marine turtle populations, with fishers stating that greater effort is required to land elasmobranchs and marine turtles than in the past (Cooke, 1997; McVean et al., 2006; Robinson & Sauer 2013). It is almost certain that elasmobranch populations have declined in living memory due to the high number of personal reports from fishers on the disappearance of large sharks from nearshore fishing sites, and the decrease in the numbers of sharks they can land per day, and therefore greater effort is required to maintain their livelihoods (G. Cripps pers. Comm.).

Global declines in both groups of species, often as a result of fisheries overexploitation, is therefore not only a conservation issue, but also one of food security for many coastal populations. The continued legal take of >42,000 turtles.year^{-1} highlights that for some countries the take of marine turtles is an important part of livelihoods. Although all species of marine turtle are on the IUCN Red List due to large declines in population numbers from past commercial exploitation (IUCN, 2015), recoveries in many rookeries have been reported worldwide (Troëng & Rankin, 2005; Broderick et al., 2006; Stokes et al., 2014; Weber et al., 2014). Such recoveries are not known in Madagascar, firstly due to the fact that the majority of nesting populations are not monitored so data do not exist, and secondly, that many are small nesting populations under continued pressure from direct take of nesting females and eggs (Rakotonirina & Cooke, 1994; Gladstone et al., 2003; Walker & Roberts, 2005). The decline in global shark populations has been of growing interest in the last decade with legislation, management and conservation measures rapidly changing as new studies continue to highlight large population declines and greater numbers of species at risk of extinction (Baum et al., 2003, 2004; Ferreti et al., 2010; Worm et al., 2013). Recent studies have not only highlighted the high percentage of shark species threatened with extinction, with 40% of Europe's sharks and rays now listed as threatened (Nieto et al., 2015), but almost half of the 1,041 species assessed in Dulvy et al., (2014) are listed as Data Deficient.

Effective legislation is required to ensure that species of conservation concern are fully protected from overfishing by domestic and foreign fleets in Madagascar's waters. Legislation regarding marine turtles is incompatible with local customs, meaning that it is ignored by fishers, regional and national authorities (Lilette, 2006; Gibbons, 2013, 2014). Many countries have ensured that legislation for marine turtles both protects the most reproductively valuable parts of the population (eg.

large adults, nesting females) whilst making provisions for customary take (Bräutigam & Eckert, 2006; Richardson et al., 2006; Havemann et al., 2007). However, significant levels of illegal take can still occur within these countries as monitoring and enforcement of marine turtle fisheries can be difficult when dealing with species, number, size or seasonal regulations (Bräutigam & Eckert, 2006; Maison et al., 2010), especially against a backdrop of long-standing cultural significance (Buden & Edward, 2001; Bell et al., 2006; Mancini & Koch, 2009).

The high prices paid for shark fins and the fact that sharks are also targeted by international vessels, means that the strength of international legislation and multilateral agreements are vital for long-term management and reduction in overfishing. In 1999 the Food and Agriculture Organisation (FAO) developed the International Plan of Action for the Conservation and Management of Sharks (IPOA-sharks), and as of 2012, 18 of the top 26 shark fishing countries or territories (responsible for 84% of global shark catches reported to the FAO 2000 to 2009) had adopted a National Plan of Action (Fischer et al., 2012). However, a review NPOA’s highlighted that not all guidelines set out by the FAO were reflected within the plan, with missing information on timelines, action plans to reduce threats to sharks, measurable targets, or how the plan is integrated with the existing legal framework and fisheries management (Fischer et al., 2012; Davis & Worm, 2013).

It is a considerable challenge to develop management schemes that can fit the complex and varied nature of SSF, and data deficiency and a lack of appropriate legislation can only exacerbate issues. The transfer of management rights to local communities is one way that management of marine resources can be improved, and is particularly relevant in countries such as Madagascar where capacity for monitoring and management of a vast coastline is beyond the capacity of the current resources (Le Manach et al., 2012). Effective local management is dependent on buy-in and locally-led enforcement and can be enhanced through participatory monitoring.

The use of participatory methods can not only be cost effective for gathering data, especially in such a remote environment, but can help to improve buy-in to conservation through building community capacity and ownership of natural resources (Danielsen, 2005, 2009; Holck, 2008; Fazey et al., 2010). Participatory methods can empower and equip communities to be able to manage their own natural resources. The participatory data collection methods described in Chapters 1 and 3 to collect information on the traditional shark and turtle fisheries in SW Madagascar, are also used to collect information on the octopus fishery (Benbow et al., 2014). The octopus fishery is a key source of income for the local population and data collected by over 30 community data collectors feeds into local management decisions on the timing and placement of temporary octopus fishing closures. The management of the octopus fishery catalysed wider marine conservation in SW Madagascar and directly led to the creation of Madagascar’s first locally managed marine area (LMMA), *Velondriake* (Andriamalala & Gardner, 2010; Oliver et al., 2015). Since the first octopus fishery closure in 2005, there have now been over 200 closures, along >200 km of Madagascar’s coastline, each of which is monitored and managed through participatory schemes (MIHARI, 2015). Participatory methods and consultations were also used to develop local laws, management plans and management structures for the Velondriake LMMA (Andriamalala & Gardner, 2010).

Such bottom-up, participatory methods are now part of over 60 LMMAs throughout Madagascar (Rocliffe et al., 2014), where community buy-in to conservation and management are being harnessed to fill the gap left by a lack of national capacity for natural resource management. A key part of the long-term sustainability of locally managed areas is the ability for adaptive management by communities. Developing appropriate methods for communities to monitor key resources, and ways in which these data can be analysed and information used to make decisions, is a priority for communities to be fully equipped with the tools they need for long-term natural resource management.

Participatory schemes used for natural resource management, will have strengths and weaknesses depending on the objectives of the scheme, the capacity of the community, the relationship and communication between those leading the scheme and those participating, and the relevance of the scheme in the particular environmental, social and/or cultural context. Recommendations as a result of the methods presented in this thesis, and in particular to the context of small-scale fisheries, include:

Design

- The buy-in to conservation and management from participatory schemes are likely to be best harnessed when the objectives are clear to the community, or ideally the project is designed by the community themselves.
- Time for preparation before participation schemes are started can ensure that data are collected correctly, and the right information is gathered. For

example, if collecting fisheries data, it is important to know how will fish species be identified. If they are in the local language, how will you identify them at a later stage? If local people will be trained in scientific names, how will you ensure identification is accurate enough? Short trial periods to gather baseline information on the kind of information and answers people will record can help define the strategy for the participatory scheme.

- Methods should be designed to take into account community capacity, whilst being as rigorous as possible to allow for results and impact to be analysed correctly. For example, equipment used should be a balance between that which is as simple as needed, whilst accurate enough (eg. scales measure to the degree of accuracy needed but are simple to use and read).
- Sampling design is particularly important to ensure that sufficient data are collected to either: draw conclusions on any changes in a fishery (eg. before/after/control/impact design), or that results can be scaled up to make estimates over the wider region, and to take into account missing data (due to no fishing or limits to the range that the study can afford to collect data in).
- Before starting a participatory scheme, it is important to understand what information is important for local management decisions. Other factors may be more important in decision-making (eg. the location in relation to other villages, how important the site is for fishing or local politics between villages). Therefore it is important to understand what kind of data would be used to make decisions by relevant stakeholders.

Capacity building for natural resource management

- Participatory schemes can be used to create an open dialogue between stakeholders, in particular where misconceptions may lie between the intentions of a new stakeholder. For example, in the Barren Isles where the turtle nest monitoring was done, this scheme helped to dispel myths that the NGO Blue Ventures was working with authorities to prosecute those doing illegal turtle hunting, and opened dialogue on the difficult issue of marine turtle conservation.
- Schemes can be designed to engage different parts of the community and/or section of society often excluded in management decisions (eg. women).
- Results from any participatory scheme should be fed back to the wider community at regular intervals so that the objectives and information gathered are continually shared. This should also reduce the potential for miscommunication surrounding any participatory scheme, and to ensure it is transparent.
- Those directly engaging in participatory schemes can become key local voices in the reasons behind the scheme, or wider conservation and management initiatives it is contributing to within their respective communities. Ensuring that those involved in the scheme receive training and education in the wider conservation and management objectives of the programme can build their capacity, broaden their ability to work within the scheme and promote further engagement.

The livelihoods and food security of some the world's most marginalised groups of small-scale fishers are dependent on the long-term health of marine turtle and elasmobranch populations in Madagascar. Within Madagascar, work to improve engagement of local fishing communities in the management of both groups of animals, including nesting marine turtles, should be a priority, whilst at the national level, improvements in legislation and fishing access agreements should be used to ensure that external interests are not prioritised above those of the small-scale fisher. Declines in the SSF sector have already been predicted and have serious implications for Madagascar's food security. Participatory approaches can only help to strengthen the ability for Madagascar's growing network of community managed areas to improve the country's capacity for natural resource management.

References

Andriamalala, G. & Gardner, C. J. (2010) L’utilisation du dina comme outil de gouvernance des ressources naturelles : leçons tirés de Velondriake, sud-ouest de Madagascar. *Tropical Conservation Science,* **3,** 447-472.

Baum, J. K., Myers, R. A., Kehler, D. G., Worm, B., Harley, S. J. & Doherty, P. A. (2003) Collapse and Conservation of Shark Populations in the Northwest Atlantic. Science, 299, 389-392.

Bell, C., Blumenthal, J., Austin, T., Solomon, J., Ebanks-Petrie, G., Broderick, A. & Godley, B. (2006) Traditional Caymanian fishery may impede local marine turtle population recovery. Endangered Species Research, 2, 63-69.

Benbow, S., Humber, F., Oliver, T. A., Oleson, K. L. L., Raberinary, D., Nadon, M. & Harris, A. (2014) Lessons learnt from experimental temporary octopus fishing closures in south-west Madagascar: benefits of concurrent closures. African Journal of Marine Science, 36, 31-37.

Béné, C., Macfadyen, G. & Allison, E. H. (2007) Increasing the contribution of small-scale fisheries to poverty alleviation and food security. FAO Fisheries Technical Paper. No. 481. pp. 125. FAO, Rome.

Bräutigam, A. & Eckert, K. L. (2006) Turning the Tide: Exploitation, Trade and Management of Marine Turtles in the Lesser Antilles, Central America, Colombia and Venezuela. pp. 551. TRAFFIC International, Cambridge, UK.

Broderick, A. C., Frauenstein, R., Glen, F., Hays, G. C., Jackson, A. L., Pelembe, T., Ruxton, G. D. & Godley, B. J. (2006) Are green turtles globally endangered? Global Ecology and Biogeography, 15, 21-26.

Buden, D. W. & Edward, A. (2001) Abundance and Utilization of Sea Turtles on Pohnpei, Federated States of Micronesia: Islanders' Perceptions. Micronesica, 34, 47–54.

Chuenpagdee, R., Liguori, L., Palomares, M. L. D. & Pauly, D. (2006) Bottom-up, global estimates of small-scale fisheries catches. Fisheries Centre Research Reports 14(8). The Fisheries Centre, University of British Columbia, Vancouver.

Cooke, A. (1997) In The trade in shark and shark products in the Western Indian and Southeast Atlantic Oceans (eds N. T. Marshall & R. Barnett), pp. 101-130. Traffic East/Southern Africa, Nairobi.

Danielsen, F., Burgess, N. D. & Balmford, A. (2005) Monitoring matters: examining the potential of locally-based approaches. Biodiversity and Conservation, 14, 2507–2542.

Danielsen, F., Burgess, N. D., Balmford, A., Donald, P. F., Funder, M., Jones, J. P. G., Alviola, P., Balete, D. S., Blomley, T., Brashares, J., Child, B., Enghoff, M., Fjeldså, J., Holt, S., Hübertz, H., Jensen, A. E., Jensen, P. M., Massao, J., Mendoza, M. M., Ngaga, Y., Poulsen, M. K., Rueda, R., Sam, M., Skielboe, T., Stuart-Hill, G., Topp-Jørgensen, E. & Yonten, D. (2009) Local participation in natural resource monitoring: a characterization of approaches. Conservation Biology, 23, 31-42.

Davis, B. & Worm, B. (2013) The International Plan of Action for Sharks: How does national implementation measure up? Marine Policy, 38, 312-320.

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., Carlson, J. K., Davidson, L. N. K., Fordham, S., Francis, M. P., Pollock, C. M., Simpfendorfer, C. A., Burgess, G. H., Carpenter, K. E., Compagno, L. J. V., Ebert, D. A., Gibson, C., Heupel, M. R., Livingstone, S. R., Sanciangco, J. C., Stevens, J. D., Valenti, S. & White, W. T. (2014) Extinction risk and conservation of the world's sharks and rays. eLife, 3:e00590, 1-34.

FAO/Advisory Committee on Fisheries Research (2004) Report of the second session of the Working Party on Small-scale Fisheries. Bangkok, Thailand, 18 – 21 November 2003. FAO Fisheries Report. No. 735. pp. 21. FAO, Rome.

Fazey, I., Kesby, M., Evely, A., Latham, I., Wagatora, D., Hagasua, J.-E., Reed, M. S. & Christie, M. (2010) A three-tiered approach to participatory vulnerability assessment in the Solomon Islands. Global Environmental Change, 20, 713-728.

Ferretti, F., Worm, B., Britten, G. L., Heithaus, M. R. & Lotze, H. K. (2010) Patterns and ecosystem consequences of shark declines in the ocean. Ecology Letters, 13, 1055-1071.

Fischer, J., Erikstein, K., D’Offay, B., Guggisberg, S. & Barone, M. (2012) Review of the Implementation of the International Plan of Action for the Conservation and Management of Sharks. FAO Fisheries and Aquaculture Circular No. 1076. pp. 120. FAO, Rome.

Gibbons, E. (2013) The Rufford Small Grants Foundation Final Report. FANO project. Available at: http://www.rufford.org/projects/emma_gibbons.

Gibbons, E. (2014). The Rufford Small Grants Foundation Project update. FANO project. Available at: http://www.rufford.org/projects/emma_gibbons_0.

Gladstone, N., Andriantahina, F. & Soafiavy, B. (2003) Azafady Project Fanomena – Marine Turtle Conservation and Research in Southeast Madagascar. Report on Activities and Findings in the 2001-2002 Nesting Season. pp. 75. Azafady, London.

Havemann, P. & Smith, R. (2007) Community Based Management of Dugong and Turtle Fisheries. Safe-guarding culture for future generations — joining together to protect dugong and turtle fisheries for the Torres Strait. Summary of TSRA Torres Strait Dugong and Marine Turtle Project Governance and Policy Review James Cook University.

Holck, M. H. (2008) Participatory forest monitoring: an assessment of the accuracy of simple cost–effective methods. Biodiversity and Conservation, 17, 2023–2036.

IUCN (2015) IUCN Red List of Threatened Animals. IUCN, Gland and Cambridge.

Jacquet, J., Fox, H., Motta, H., Ngusaru, A. & Zeller, D. (2010) Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. African Journal of Marine Science, 32, 97-106.

Le Manach, F., Gough, C., Harris, A., Humber, F., Harper, S. & Zeller, D. (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy, 36, 218-225.

Lilette, V. (2006) Mixed results: conservation of the marine turtle and the red-tailed tropicbird by Vezo semi-nomadic fishers. Conservation and Society, 4, 262–286.

Maison, K. A., Kinan-Kelly, I. & Frutchey, K. P. (2010). Green Turtle Nesting Sites and Sea Turtle Legislation throughout Oceania. U.S. Dep. Commerce, NOAA Technical Memorandum. NMFS-F/SPO-110, 52 pp.

Mancini, A. & Koch, V. (2009) Sea turtle consumption and black market trade in Baja California Sur, Mexico. Endangered Species Research, 7, 1-10.

McVean, A., Walker, R. & Fanning, E. (2006) The traditional shark fisheries of southwest Madagascar: A study in the Toliara region. Fisheries Research, 82, 280-289.

MIHARI (2015). MIAHRI – Madagascar's locally managed marine area network. Available from: http://blueventures.org/publication/mihari-madagascars-locally-managed-marine-area-network/

NFPA, UNDP, UNICEF, ADB, COMESA, WFP, UN WOMEN, NSB, World Bank, PGDI & INSTAT (2014) 2012-2013 National Survey on Monitoring the Millennium Development Goals in Madagascar - Goal 1: Eradicate extreme poverty and hunger. INSTAT, Antananarivo.

Nieto, A. & Ralph, G. M., Comeros-Raynal, M.T., Kemp, J., García Criado, M., Allen, D.J., Dulvy, N.K., Walls, R.H.L., Russell, B., Pollard, D., García, S., Craig, M., Collette, B.B., Pollom, R., Biscoito, M., Labbish Chao, N., Abella, A., Afonso, P., Álvarez, H., Carpenter, K.E., Clò, S., Cook, R., Costa, M.J., Delgado, J., Dureuil,M., Ellis, J.R., Farrell, E.D., Fernandes, P., Florin, A-B., Fordham, S., Fowler, S., Gil de Sola, L., Gil Herrera, J., Goodpaster, A., Harvey, M., Heessen, H., Herler, J., Jung, A., Karmovskaya, E., Keskin, C., Knudsen, S.W., Kobyliansky, S., Kovačić, M., Lawson, J.M., Lorance, P., McCully Phillips, S., Munroe, T., Nedreaas, K., Nielsen, J., Papaconstantinou, C., Polidoro, B., Pollock, C.M., Rijnsdorp, A.D., Sayer, C., Scott, J., Serena, F., Smith-Vaniz, W.F., Soldo, A., Stump, E. and Williams, J.T. (2015) European Red List of Marine Fishes. IUCN Global Species Programme. European Commission, Luxembourg.

Oliver, T., Oleson, K.L.L., Ratsimbazafy, H., Raberinary, D., Benbow, S. & Harris, A. (2015) Positive catch & economic benefits of periodic octopus fishery closures: do effective, narrowly targeted actions ‘catalyze’ broader management? PLoS ONE 10(6): e0129075. doi:10.1371/journal.pone.0129075

Rakotonirina, B. & Cooke, A. (1994) Sea turtles of Madagascar – their status, exploitation and conservation. Oryx, 28, 51-61.

Richardson, P., Broderick, A., Campbell, L., Godley, B. & Ranger, S. (2006) Marine Turtle Fisheries in the UK Overseas Territories of the Caribbean: Domestic Legislation and the Requirements of Multilateral Agreements. Journal of International Wildlife Law and Policy, 9, 223–246.

Robinson, L. & Sauer, W. H. H. (2013) A first description of the artisanal shark fishery in northern Madagascar: implications for management. African Journal of Marine Science, 35, 9 - 15.

Rocliffe, S., Peabody, S., Samoilys, M. & Hawkins, J. P. (2014) Towards A Network of Locally Managed Marine Areas (LMMAs) in the Western Indian Ocean. *PLoS ONE,* **9,** 1-14.

Salas, S., Chuenpagdee, R., Seijo, J. C. & Charles, A. (2007) Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. Fisheries Research, 87, 5–16.

Stokes, K. L., Fuller, W. J., Glen, F., Godley, B., Hodgson, D. J., Rhodes, K. A., Snape, R. T. E. & Broderick, A. (2014) Detecting green shoots of recovery: the importance of long-term individual-based monitoring of marine turtles. Animal Conservation, 17, 593–602.

Troëng, S. & Rankin, E. (2005) Long-term conservation efforts contribute to positive green turtle Chelonia mydas nesting trend at Tortuguero, Costa Rica. Biological Conservation, 121, 111–116.

Walker, R. & Roberts, E. (2005) Notes on the status and incidental capture of marine turtles by the subsistence fishing communities of South West Madagascar. Western Indian Ocean Journal of Marine Science, 4, 219-225.

Weber, S. B., Weber, N., Ellick, J., Avery, A., Frauenstein, R., Godley, B., Sim, J., Williams, N. & Broderick, A. (2014) Recovery of the South Atlantic's largest green turtle nesting population. Biodiversity and Conservation, 23, 3005-3018.

Worm, B., Davis, B., Kettemer, L., Ward-Paige, C. A., Chapman, D., Heithaus, M. R., Kessel, S. T. & Gruber, S. H. (2013) Global catches, exploitation rates,and rebuilding options for sharks. Marine Policy, 40, 194-204.