Rev Fish Biol Fisheries (2022) 32:1001–1015
https://doi.org/10.1007/s11160-022-09718-7

ORIGINAL RESEARCH

Evaluating loggerhead sea turtle (*Caretta caretta*) bycatch in the small-scale fisheries of Cabo Verde

Samir Martins · Manjula Tiwari · Fernando Rocha · Edson Rodrigues · Ravidson Monteiro · Sónia Araújo · Elena Abella · Nuno de Santos Loureiro · Leo J. Clarke · Adolfo Marco

Received: 6 January 2021 / Accepted: 14 April 2022 / Published online: 9 July 2022

Abstract The incidental or target capture of sea turtles by small–scale fisheries (SSF) has been receiving increasing attention in recent years due to its high impact. Here, we evaluated the impact of the SSF on sea turtles in Cabo Verde, which hosts the largest rookery of the endangered Eastern Atlantic loggerhead turtle (*Caretta caretta*) population. This is the most comprehensive study evaluating the impact of SSF on sea turtles in the Cabo Verde Archipelago involving more than 85% of boats and more than 20% of the fishermen registered in the archipelago. Between the years of 2011 and 2014, 763 artisanal fishermen were interviewed at all the main ports and fishing communities of seven islands. Artisanal fishermen reported a mean annual capture of 1.5 turtles per boat indicating that a minimum of 1675 sea turtles could be landed per year in this fishing sector alone, with 65% in Santiago Island (which host the country's capital, Praia). Most captures (95.7%) occurred from May to September and coincided with the loggerhead turtle nesting season. These results suggest a severe impact of the SSF on adult loggerheads turtles in Cabo Verde as well as green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) juvenile turtles. To mitigate this impact, measures such as revising the current legislation for fisheries, the supervision and control of landings, especially in the most remote ports of the Archipelago, the regulation of the SSF during the nesting season around the main nesting areas, awareness–raising campaigns, sustainable

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11160-022-09718-7.

S. Martins (✉) · F. Rocha · E. Rodrigues · E. Abella · A. Marco
BIOS.CV – Conservation of the Environment and Sustainable Development, CP 52111 Sal Rei, Boa Vista Island, Cabo Verde
e-mail: ilheuraso@gmail.com

S. Martins · N. de Santos Loureiro
Universidade do Algarve, Campus de Gambelas, 8000–117 Faro, Portugal

M. Tiwari
Ocean Ecology Network, Research Affiliate to NOAA–National Marine Fisheries Service, Marine Turtle Ecology and Assessment Program, Southwest Fisheries Science Center, La Jolla, CA 92037, USA

R. Monteiro
University of Cabo Verde, CP 163 Mindelo, Cabo Verde

S. Araújo
National Directorate of Environmental, Chã d'Areia, CP no 332-A, Praia, Santiago, Cabo Verde

L. J. Clarke
School of Ocean Sciences, Bangor University, Menai Bridge LL59 5AB, UK

A. Marco
Estación Biológica de Doñana, CSIC, C/Américo Vespucio s/n, 41092 Sevilla, Spain

activities, and alternative sources of income in fishing communities are recommended.

Keywords Sea turtle · Small · Scale fishery · Illegal capture · Cabo Verde · West Africa

Introduction

Small–scale fisheries (SSF) occur in coastal waters worldwide and often form the basis of the fishing sector in economically developing countries (Salas et al. 2007; Béné et al. 2010; Chuenpagdee and Jentoft 2018). However, relative to large–scale fisheries and other industries competing for marine space, resources, and government attention, SSF often get marginalized (Chuenpagdee and Jentoft 2018). Enforcement and management measures tend to be limited and many remote landing ports for SSF preclude access thereby making it challenging to evaluate the impact of these fisheries on marine resources as well as protected species (Salas et al. 2007; Chuenpagdee and Jentoft 2018). Consequently, industrial fisheries have often been considered the most important threat to large marine vertebrates (Soykan et al. 2008; Wallace et al. 2013; Lewison et al. 2014; Coelho et al. 2015), however, SSF are increasingly emerging as a serious threat to these megafauna (Lum 2006; Moore et al. 2010; Mancini et al. 2012; Guebert et al. 2013; Manzan and Lopes 2015; Alfaro-Shigueto et al. 2018). It is estimated that hundreds of thousands of sea turtles are captured annually in SSF around the world (Koch et al. 2006; Moore et al. 2010; Guebert et al. 2013; Lagueux et al. 2017; Alfaro-Shigueto et al. 2018). Some researchers have speculated that the impact of SSF on sea turtles could be equal to or exceed the incidental catch levels in industrial fisheries (Lum 2006; Peckham et al. 2008; Alfaro-Shigueto et al. 2018). Furthermore, in poor coastal communities, intentional capture of sea turtles also occurs for their meat, eggs and derivatives and has been associated with the decline of many sea turtle populations (Fretey 2001; Witherington and Frazer 2002; Koch et al. 2006; Loureiro and Torrão 2008; Marco et al. 2012). However, these numbers are more challenging to estimate because fishermen may hide the real number of captures because sea turtles are protected species in most countries (Humber et al. 2014).

In the northeast Atlantic, the largest loggerhead turtle (*Caretta caretta*) subpopulation nests in the Cabo Verde Archipelago (15°6´ N, 23º37´ W), off the coast of Mauritania/Senegal (Marco et al. 2012; Laloe et al. 2019, Fig. 1), and is classified as Endangered (Casale and Marco 2015). The main anthropogenic factor impacting this population is direct capture and consumption of turtles (Loureiro and Torrão 2008; Marco et al. 2011, 2012; Martins et al. 2013; Hancock et al. 2017; Araújo 2019), coastal urbanization on the beachfront and light pollution (Cozens and Taylor 2011) and bycatch (Coelho et al. 2015). It is estimated that hundreds of turtles are caught each year on the nesting beaches and in the waters of the archipelago (Loureiro and Torrão 2008; Marco et al. 2012; Martins et al. 2013; Araújo 2019), however, information about capture at sea and trade in turtle meat among the islands is scarce. Previous studies have suggested that artisanal fishermen target and catch sea turtles in the waters of Boa Vista and Maio Islands for local markets in Praia, the capital of Cabo Verde, on Santiago Island (Cabrera et al. 2000; MADRRM 2008; Lopes et al. 2016; Hancock et al. 2017). However, these studies focused on only three islands, and there is a crucial need for a broader evaluation of the impact of SSF on sea turtles in the archipelago, given that the distribution of sea turtles and the number of fishermen vary among the islands (MADRRM 2008; DGRM 2014).

The lack of in–depth knowledge on the impact of different fishing gears used in the archipelago and the areas and periods of greatest fisheries–sea turtle interactions are major gaps in the sea turtle conservation effort in Cabo Verde, and consequently, a barrier for designing efficient conservation strategies (MADRRM 2008). The present study addresses some of these gaps by, estimating sea turtle captures in the SSF of Cabo Verde, evaluating the periods of highest accidental captures, and determining which fishing gears have the greatest impacts. We used data from direct interviews of fishermen, that are considered an inexpensive, and relatively fast methodology when compared with onboard observers' programs (Moore et al. 2010; Lucchetti et al. 2017).

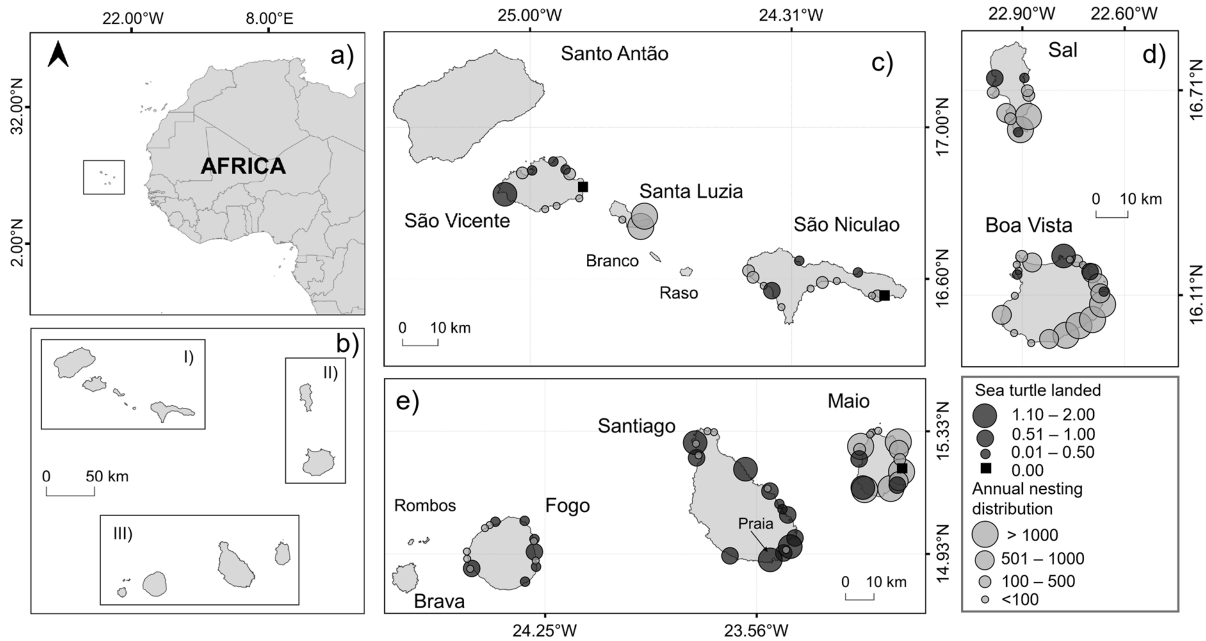

Fig. 1 Map of Cabo Verde Archipelago showing the archipelago location (latitudes and longitudes) and the capture rate of loggerheads at the main ports. Data on annual nesting distribution for Santa Luzia Island come from Rocha et al. (Rocha et al. 2015); São Nicolau Island from Conceição and Neves, (2009); Sal Island from Taylor and Cozens, (2010) and Laloë et al. (Laloë et al. 2019); Boa Vista from Marco et al. (2012); Maio Island from Cozens et al. (2011) and Martins et al. (2013); Santiago Island from Loureiro (2007), Loureiro and Torrão (2008) and Mendes (2010). Data from São Vicente and Fogo come from internal reports (Correira, Lopes and Dinis personal communication)

Methods

Study area

The Cabo Verde Archipelago, located 455 km of off the west coast of Africa, is comprised of ten islands with one uninhabited island (Santa Luzia), and various islets (Fig. 1). The last population census in 2010 recorded 488,040 inhabitants, distributed unequally among the islands, with a large proportion of the population (46%) living on the main island of Santiago (INE 2020). The mean gross domestic product per capita is USD $3,651 (INE 2020). The tourism development sector contributes the largest income (58%), followed by transportation, telecommunications and basic services at 21%, industry at 17%, and fisheries and agriculture at 4% (INE 2020).

Within the archipelago, 90–95% of loggerhead nesting activities are recorded on the islands of Santa Luzia, Sal, Boa Vista, Maio and islet Rombos (Marco et al. 2012; Martins et al. 2013; Laloe 2019; Rocha et al. 2015; Dinis, personal communication). The archipelago also has important foraging grounds for green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) turtles (Marco et al. 2011). Leatherback (*Dermochelys coriacea*) and olive ridley (*Lepidochelys olivacea*) turtles are less common in these waters (Marco et al. 2011; Varo-Cruz et al. 2011). The use of sea turtles and their by–products is an illegal activity in Cabo Verde, subject to penalization (Legislative Decree no 1/18—21/05/2018) that included a penalty of up 2.720 € and/or up to three years of custodial sentences in jail and the loss of all equipment used to handle sea turtles (BOCV 2018).

Description of SSF fishing fleet and gear in Cabo Verde

The SSF fleets in Cabo Verde are composed of small vessels between 3 and 12 m in length (Supplementary material 1), operated exclusively by males (DGRM 2014; González et al. 2020); they are usually powered by oars, a sail or an outboard engine of about 5 to 25 horsepower (BOCV 2016; Belhabib et al. 2018).

The number of fishermen on each boat varies from 1 to 12, with an average of 3 fishermen per vessel, according to vessel size and fishing practice (DGRM 2014; Belhabib et al. 2018). The species caught are represented by large oceanic pelagic, small coastal pelagic, demersal fish and lobsters (Wirtz et al. 2013; González et al. 2020). Some species of molluscs and sharks are also commercialized. Handlines, gillnets, purse seines and beach seines are the most important fishing gear. Spear fishing (with or without an oxygen tank) is also practiced.

Handlines vary from 10 to 450 m, and usually each fisherman takes his own line with one to five hooks baited with live or artificial bait (INDP 1993; DGRM 2014; BOCV 2016). The long length of the line (450 m) is due to the way fishermen catch the large pelagics. If the line is short, the force of these fish can break the line quite easily. So, to prevent the line from breaking, fishermen use a long line to allow the hooked fish to swim and become tired before it is pulled into the boat.

Gillnets are usually 100 m long and 3–5 m height, with 30–40 mm mesh size (i.e. measured from knot-to-knot) and are used to catch small coastal pelagic fish (DGRM 2014; BOCV 2016; González et al. 2020). The purse seine net is typically 165 m long and operated from a 9–12 m boat (BOCV 2016) and used to target mainly small pelagic coastal fishes (González et al. 2020). Beach seines usually have a 30–160 m long headrope, are from 2 to 10 m high and may or may not have a bunt (bag or lose netting). The bunt height ranges from 6 to 10 m. The mesh size, in the center of seine, varies between 16–20 mm (DGRM 2014; BOCV 2016). Spear fishermen usually dive with scuba gear and use a boat 3–7 m in length (INDP 1993; DGRM 2014; BOCV 2016).

Surveys

The impact of fisheries on sea turtle populations has traditionally been assessed using data collected by trained on-board observers (Soykan et al. 2008; Carruthers and Neis 2011; Coelho 2015). However, in the case of SSF, on board observations pose major challenges due to the small size and large number of vessels participating in the fishing activities (Salas et al. 2007; Soykan et al. 2008). Because the capture of a sea turtle may be a rare event, sampling effort with direct on-board observations has to be very high to be representative. This implies costs for the fishing vessels and may be time consuming (Lewison et al. 2004). A program of interviews with the fishermen can be a viable alternative to direct observations. The fishermen´s knowledge and skills accumulated over the years, known as local ecological knowledge (LEK) has been widely used as a tool to collect information on the environment, the resources and fishing practices, that is not easily accessed through conventional ecological research for biodiversity conservation (Gilchrist et al. 2005; Moore et al. 2010; Alfaro-Shigueto et al. 2018). The use LEK is very valuable in Cabo Verde where the SSF is widespread among islands and islets and the country has limited research infrastructure.

Interviews with fishermen were carried out from 2011–2014 at all the main ports and fishing communities of Cabo Verde on the islands of: Santiago, Fogo, São Vicente, São Nicolau, Sal, Boa Vista and Maio (Table 1; Fig. 1). We chose these islands based on the following criteria: (i) they have the most sea turtle nesting activities; (ii) they are the most populated islands and (iii) and they have accessible ports with known sea turtle landings. Nevertheless, we acknowledge that the estimation of sea turtle captures will be biased by these criteria.

Our sample size was based on the number of boats registered in the official census of National Directorate of Fisheries on each island (MIEM 2011; DGRM 2014). On the islands where this information did not exist, we conducted our own counts at the ports when boats were not out fishing and through questionnaires for fishermen. For each island we ensured that the sample size was sufficient for representative results (95% confidence level, with 5% confidence interval; Cocks and Torgerson 2013).

The questionnaire for the fishermen included 21 open and 39 closed questions on the fishing activity in general, gear, properties, sea turtle capture per year etc., and were completed in–person at the fisherman's home or at landing ports by primarily the Cabo Verdean authors. The fishermen were chosen opportunistically through snowball sampling, based on their availability to respond to the questionnaire and if fishing was their main activity. The interviewers ensured that each interviewee belonged to a different boat and vice–versa. The questions covered fishers' practices and background, fishing gears used, number and or dimensions of fishing gears, time and locations of

Table 1 Data on the artisanal fisheries in the islands of Cabo Verde

Island	Ports	Interviews (N)	Vessels (N)	Fishermen (N)	Handline*	Gillnets*	Purse seine*	Beach seine*	Under water fishing*
São Vicente	4	76	93*	279*	55	4	11	5	1
São Nicolau	5	95	95**	240*	78	6	8	0	3
Sal	3	66	153**	360*	60	3	2	0	1
Boa Vista	4	34	136**	183*	33	0	0	0	1
Maio	4	79	79**	207*	65	0	2	5	7
Santiago	32	291	492*	1476*	193	38	53	3	4
Fogo	12	122	122**	327*	111	0	7	3	1
Total	64	763	1170	3072	595	51	83	16	18

*Data from Directorate General of Marine Resources (DGRM 2014). The last census was in 2011

**This study

capture of sea turtles (Supplementary material 2). When fishermen used more than one gear type, we asked them to indicate the fishing gear that they most commonly use. Whilst this means that information on gear-specific capture rates was not collected, fishermen indicated that they could not easily or accurately attribute capture rates to a particular gear due to a combination of gears being used by each fisherman.

Following the Moore et al. (2010) methodology and building on our knowledge of fisheries activity in Cabo Verde, all interviews took less than 15 min. Illustrations of sea turtles were used for species identification (Supplementary material 3) because the common names varied among different communities and islands. The interviewers ensured that all fishermen were aware that the surveys were voluntary and that their names would remain confidential, in accordance with our ethics permission (National Directorate of Environment Ref No: DGA 02/2012 and DGA 23/2014).

Data analysis

To estimate overall captures of sea turtles by the Cabo Verdean fishing fleet, we first estimated the number of individual turtles caught by each boat per year in each of the ports sampled, as indicated by fishermen (including all zeros) (Moore et al. 2010). In Cabo Verde, most fishermen do not own boats, but rent different boats for fishing. When a fisherman reported the number of turtle captures per boat, he was therefore estimating average captures over the different boats that he had used for fishing. For example, if a fisherman indicated that he caught 1–3 turtles per year, we took the mean annual turtle capture as 2 turtles per boat per year, over all the different boats that he had used. Using these reported values of turtle captures per boat, we calculated the mean value of turtle captures per boat per year for each port. We then extrapolated these estimates across the entire Cabo Verde fleet by using the number of registered boats at each port. These estimates are considered minimum values because it is unlikely that fishermen are exaggerating their captures. We added the mean values of captured turtles per port for all ports on each island to obtain an estimated number of turtles captured per year and per island. Finally, we added the mean values of captured turtles per year from each island to obtain an estimate of the total number of turtles captured per year in the group of islands studied. Given the lack of gear-specific capture rates due to fishermen's uncertainty in attributing the sea turtle captures to an individual gear type, and a lack of information on gear type used for the wider Cabo Verdean fishing fleet, we did not incorporate gear type into our extrapolation of sea turtle captures by the entire fleet. Rather, we used the average annual capture rates per boat for each port, which average across all gear types used by the fleet.

Factors that may have influenced sea turtle capture responses in the questionnaire were organized as follow: a) questions that required numerical data (age, years of fishing activity, number of fishermen by boat, boat length) were grouped together; b) fishing effort was coded as time intervals: < 7 h, 7–12 and > 12 h spent at sea because the fishermen don´t provide the exact time; c) vessel ownership had a yes or no response; d) fishing in other islands had a yes or no response; e) perception of fishermen about national sea turtle protection laws had agree, disagree or no opinion responses.

Statistical analyzes were done using the R software programming language v.3.6.1 (R Core Team 2020). In order to investigate the effect of our explanatory variables on the number of sea turtle captures, we ran a zero-inflated generalized linear model (GLM), with a negative binomial error distribution and a logit link function, to account for overdispersion due to high counts of zero. This is a two-part modelling technique that separately models the probability of zeros (i.e. that no captures occur, the zero-inflated model component) vs. larger counts, using a binomial error distribution with a logit link, and the probability of captures, which are not guaranteed (the count model component), using a negative binomial error distribution with a logit link. This model structure has been demonstrated to be well suited to modelling bycatch estimates (Minami et al. 2007). Candidate models were ranked according to Akaike Information Criteria (AIC) scores, with the best model identified by the lowest AIC score. We used the "MASS" package for the GLM analyzes (*v7.3–51-4*; Venables and Ripley 2002) and the "MuMlm" to rank our models according to AIC scores (*vi.43.15*, Barton 2019).

We used the Chi–square test and *F*–test to test for the differences in proportions between variables using the R software (R Core Team 2020). Statistical significance level was alpha = 0.05.

Results

Sea turtle captures

A total of 763 interviews were conducted (Table 1): 76 in São Vicente, 95 in São Nicolau, 66 in Sal, 34 in Boa Vista, 79 in Maio, 291 in Santiago and 122 in Fogo; only 4 fishermen refused to answer the questionnaire. With the exception of Santiago, all ports were visited on each surveyed islands. On the islands of São Nicolau, Maio and Fogo it was possible to interview all active boats (Table 1). Of the fishermen interviewed, 482 (63.2%) declared that they had never caught turtles. Information of the state of sea turtle when captured was not recorded, i.e., if the animal presents any visible injuries or deaths. A mean capture rate of 1.5 turtles per year per vessel was calculated in the SSF studied across all gear types and vessels. Using the number of all fishing vessels registered in the islands studied, an annual catch of 1,675 sea turtles was estimated in the seven islands studied. The contribution of Santiago Island to the number of turtles caught was 65.0% whereas the other islands had minor contributions (Fig. 1; Table 2). São Nicolau had the lowest annual capture value of 0.4 capture per boat (Fig. 1; Table 2). The rate of capture of sea turtles varied among fishing gear types ($X^2 = 453.9$, df = 4, $p < 0.001$). Among the fishermen who reported captures of sea turtles, the handline was the most represented (69.7%, n = 196), followed by purse seines (13.8%, n = 39) and gillnets (12.8%, n = 36). Other fishing gear (beach seine and spear fishing) represented the remaining 3.5% of captures (n = 10) (Fig. 2). The percentage of fishermen who reported the capture of sea turtles (36.8%) varied

Table 2 Estimated annual capture rates of sea turtles in the small fisheries of Cabo Verde for the islands covered by a program of fishermen interviews conducted at the main ports and fishing communities

Islands	Fishermen who captured turtles (N)	Estimated mean annual captures (N/boat)	Estimated mean annual capture (N)
São Vicente	14	1.0	93.9
São Nicolau	21	0.4	39.2
Sal	26	1.0	156.1
Boa Vista	11	0.9	127.8
Maio	19	1.1	78.7
Santiago	156	2.2	1092.2
Fogo	34	0.8	87.2
Total	281	1.5	1675.1

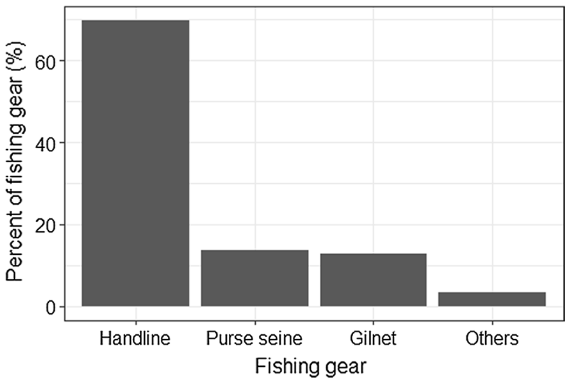

Fig. 2 Representation (in percentage) of fishing gear used in sea turtle capture in the small–scale fisheries of Cabo Verde (n = 227 fishermen). Others correspond to beach seine and spear fishing

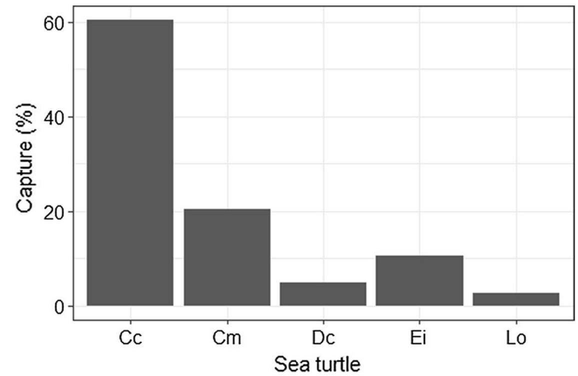

Fig. 4 Frequency of sea turtle species captured in the small–scale fisheries of Cabo Verde (n = 227 fishermen). Cc = loggerhead (*Caretta caretta*); Cm = green turtle (*Chelonia mydas*); Dc = leatherback (*Dermochelys coriacea*); Ei = hawksbill (*Eretmochelys imbricata*); Lo = olive ridley (*Lepidochelys olivacea*)

among islands from 18.4% (n = 14) in São Vicente to 53.6% (n = 156) in Santiago (Table 1; Fig. 1).

Information on the temporal distribution of sea turtle captures was reported only by 227 of the 281 fishermen who reported capturing sea turtle. Sea turtles were captured throughout the year (Fig. 3), though the temporal distribution is not consistent ($X^2 = 139.9$, df = 11, $p < 0.001$), with more captures reported from May to September (95.7%). The lowest frequency of captures was found in the winter months.

All five sea turtle species present in Cabo Verdean waters are brought in regularly by local fishing boats (Fig. 4). Among them, 80.7% (n = 227) had captured loggerhead turtles, 27.4% (n = 77) had captured green turtles, 7.8% (n = 22) had captured leatherback turtles, 14.2% (n = 40) had captured hawksbill turtles, and only 3.6% (n = 10) had captured olive ridley turtles. Loggerheads were the most common species captured on all islands ($X^2 = 30.56$, df = 24, p = 0.17).

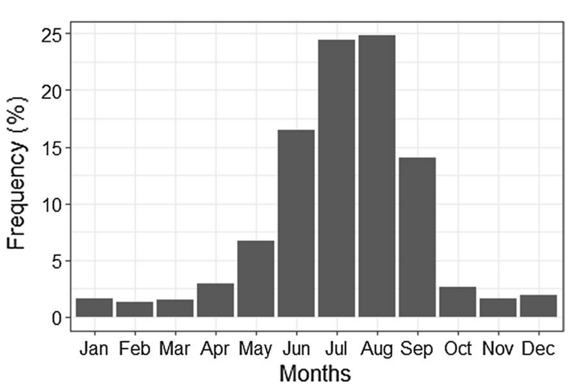

Fig. 3 Temporal variation in sea turtle captures (%) in the small–scale fisheries of Cabo Verde. n = 227 fishermen

Fishermen' behaviors and perception

At least 70.4% (n = 537) of the fishermen said that if they accidentally catch a live, healthy turtle in their fishing gears, they would release it back to sea. Nevertheless, 11.7% (n = 89) of the fishermen admitted that they would use it for consumption, 10.2% (n = 78) confirmed that they would sell the turtle for human consumption, and 7.7% (n = 59) fishermen did not answer this question. However, if the sea turtle is caught injured or dead, then 46.4% (n = 354) of the fishermen indicated they would release it back to sea, 18.3% (n = 140) would deliver it to the authorities on land, 14.4% (n = 110) would use it for consumption or sell it, and 2.2% (n = 16) recognized that the boat owner would decide the fate of the turtle. At least 49.9% (n = 381) of the fishermen confirmed that other fishermen regularly capture sea turtles within their communities, and 46.0% (n = 351) of the fishermen admitted that they eat turtle meat, 28.1% (n = 214) sell turtle meat, and 25.0% (n = 191) affirmed that they eat and sell turtle meat.

Significant differences were detected in the fishermen' perception about sea turtle abundance from when they first started fishing compared to present

Table 3 Summary of most parsimonious zero-inflated generalized linear model (GLM) with a negative binomial error distribution and a logit link function to test the effect of predictor variables on sea turtle capture in the seven islands studied in Cabo Verde (n = 763)

Dependent variable	Predictor variables	Count Intercept	df	logLik	AIC	ΔAIC	weight
Number of sea turtle captures	nfshr + law + years	1.268	9	− 1144.0	2310.4	0.00	0.409
	boatl + nfshr + law + years	1.286	13	− 41,142.4	2311.3	0.83	0.262
	fshng + nfshr + law + years	1.323	13	− 1142.8	2312.2	1.72	0.168
	boatl + fshng + nfshr + law + years	1.359	15	− 1141.3	2313.2	2.77	0.099
	own_boat + nfshr + law + years	1.288	13	− 1143.9	2314.2	3.75	0.061
	own_boat + boatl + fshng + nfshr + law + year	1.374	17	− 1141.2	2317.2	6.79	0.013
	fshng + nfshr + law + years + gear	1.333	21	− 1139.1	2321.5	11.16	0.002
	boatl + fshng + nfshr + law + years + gear	1.358	23	− 1137.3	2322.0	11.64	0.001

The models ares ranked by lowest to highest Akaike Information Criterion (AIC) values (years = number of years of fishing activity, boatl = boat length, nfshr = number of fishermen working in the boat, fshng = fishing at other islands, law = perception of fishermen about national sea turtle protection laws, ownboat = fisherman owns his own boat, gear = main gear type used)

times ($X^2 = 328.6$, df = 2, $p < 0.001$). At least 58.1% (n = 443) confirmed that turtles were more abundant in the past, 5.0% (n = 38) indicated that there are more turtles now, and 36.0% (n = 275) believed that the turtle population had remained stable. The majority of the fishermen believed that captures at sea were more frequent in the past (67.0%, n = 511), 29.0% (n = 221) thought there were fewer captures now, and 4.1% (n = 31) stated that there had been no temporal changes in turtle captures ($X^2 = 459.5$, df = 2, $p < 0.001$).

The best-fitting model (GLM) applied to data on the number of sea turtle captured included the years of fishing activity, the number of fishermen working in the boat, and perception of fishermen about national sea turtle protection laws (Table 3). Of these predictors, only the number of fishermen working on the boat and the years they had been fishing had a significant effect on sea turtle capture rates, and only identified in the zero-inflation model (Table 4). Both these factors had a negative impact (Table 4), with exponentiated model coefficients indicating that every additional fisherman working aboard the vessel and every year of fishing experience both reduced the likelihood of capturing a turtle by a factor of one (Table 5).

The number of turtles captured did not vary with fishermen's age (F = 0.75, $p > 0.388$) nor with belonging to a fishermen's association ($X^2 = 0.145$, df = 1, p = 0.704). However, the capture of sea turtles was affected by the years of fishing activity (F = 7.209,

Table 4 Results of the lowest AIC two-part zero-inflated GLM applied to data on the number of sea turtle captures

Variable	Estimate	S.D	z-value	Probability
Count model				
Intercept	1.268	0.209	6.061	**< 0.001**
Law (Disagree)	− 0.581	0.328	− 1.776	0.076
Law (No Opinion)	0.368	0.224	1.644	0.100
Number of fishermen	− 0.001	0.024	− 0.054	0.957
Years fishing	− 0.009	0.006	− 1.628	0.104
Zero-inflation model				
Intercept	0.853	0.294	2.898	**0.004**
Law (Disagree)	− 1.049	0.957	− 1.096	0.273
Law (No Opinion)	0.415	0.330	1.257	0.209
Number of fishermen	− 0.095	0.048	− 1.980	**0.048**
Years fishing	− 0.028	0.01	− 2.576	**0.010**

Significant predictors are indicated in bold

Table 5 Exponentiated model coefficients from the best-fitting two-part zero-inflated GLM applied to data on the number of sea turtle captures, indicating the effect of each predictor variable included in the model, showing results of the count and zero-inflation model components separately

Coefficient	Count model	Zero-inflation model
Intercept	3.554	2.346
Law (Disagree)	− 0.559	− 0.350
Law (No Opinion)	1.445	1.514
Number of fishermen	− 0.999	− 0.909
Years fishing	− 0.991	− 0.972

$p=0.007$), the boat length ($F=22.89$, $p<0.001$), the number of fishermen working in the boat ($F=881.8$, $p<0.001$), the fishing effort ($X^2=6.25$, $df=2$, $p=0.044$), whether fishermen went to other islands to fish ($X^2=73.596$, $df=1$, $p=0.007$), and the attitude of fishermen toward turtle conservation ($X^2=25.294$, $df=2$, $p<0.001$).

The age of the interviewed fishermen ranged from 16 to 81 years old (mean = 39.1, SD = 12.8) with no significant differences in fishermen's age among the islands ($F=0.977$, $p=0.404$; $n=662$), and no significant difference in the average age of the fishermen who acknowledged catching sea turtles ($F=0.798$, $p=0.795$; $n=757$).

Regarding the perception of fishermen about national sea turtle protection laws, 19.0% (n = 145) of the fishermen totally agreed with the laws, 63.0% (n = 481) agreed, 1.7% (n = 13) disagreed with the law, 3.1% (n = 24) totally disagreed and 1.8% (n = 14) did not have any opinion.

Different reasons were provided in support of the national laws for sea turtle conservation: 32.0% (n = 244) of the fishermen responded that sea turtles are endangered, 21.2% (n = 162) responded that the law has to be respected, and 11.7% (n = 89) responded that sea turtles are the natural heritage of Cabo Verde and deserve protection. Regarding reasons to reject the turtle protection laws, 9.8% (n = 75) responded that they do not have an opinion, 3.3% (n = 25) stated that they need the income from turtle sales and 1.3% (n = 10) said that they have been catching them traditionally since they started fishing.

Discussion

Sea turtle captures

This is the most comprehensive study evaluating the impact of Small–scale fisheries (SSF) on sea turtles in the Cabo Verde Archipelago involving more than 85% of boats and more than 20% of the fishermen registered in the archipelago (INDP 1993; DGRM 2014).

Although Santiago Island has the lowest loggerhead sea turtle nesting activity in the archipelago (Marco et al. 2011; Araújo 2019), it reported the highest capture rate. This is probably because fishermen from Santiago fish in the waters of Boa Vista and Maio Islands. These islands (Santa Luzia, Boa Vista, Maio and Rombos islet) together host more than 90% of the loggerhead sea turtle nesting activity (Marco et al. 2011, 2012; Martins et al. 2013; Rocha et al. 2015), in addition to supporting the largest fishing stocks in the archipelago (INDP 1993; BOCV 2016), and attract fishermen from Santiago who capture turtles that are then landed in remote ports with deficient or non–existent supervision or enforcement. São Vicente, São Nicolau and Fogo Islands also have low nesting, and fishermen from these islands may capture sea turtles in fishing areas around the Natural Reserve of Santa Luzia (between São Vicente and Santa Nicolau) and the Integral Reserve of Rombos (close to Fogo). However, we would like to highlight that our estimation of sea turtle captures may be positively biased because the interviews targeted areas with known sea turtle landings and high sea turtle nesting activities.

The distribution of turtle captures reflects the abundance and the natural distribution of the species in the archipelago. The most commonly captured species was the loggerhead sea turtle, coinciding with when they are most abundant in Cabo Verde, during the nesting season from June to October (Marco et al. 2011, 2012). This population is one of the world's most endangered populations (Wallace et al. 2011). Juvenile green and hawksbill turtles from western Africa and the Caribbean rookeries (Monzón-Argüello et al. 2010a; Monzón-argüello et al. 2010b) that forage in Cabo Verde waters are the second most commonly captured species.

The highest number of captures recorded from handline gear is probably because this gear is most extensively used (75.6%) in Cabo Verde since it is inexpensive and efficient (INDP 1993; DGRM 2014; BOCV 2016). Accidental capture by handline may be the result of turtles being attracted to the bait and swallowing the hook or because of foul–hooking or entanglement in the fishing line (Poonian et al. 2009). Although gillnets and purse seines are responsible for high sea turtle captures in other regions (Lum 2006; Peckham et al. 2008; Soykan et al. 2008; Poonian et al. 2009; Moore et al. 2010; Mancini et al. 2012; Guebert et al. 2013; Manzan and Lopes 2015; Alfaro-Shigueto et al. 2018; Ortiz-Alvarez et al. 2020), these fishing gears have shown low captures in Cabo Verde possibly due to their limited use (6%) in Cabo Verde's SSF (DGRM 2014). Likewise, captures by purse seines and spear fishing have shown low capture rates in this study because of their limited use. The widespread handline and hook use characterizes the highly artisanal nature of the fishery in Cabo Verde, which is probably linked to the low socio–economic status of this sector and may be an incentive for fishermen to catch sea turtles (Béné et al. 2010).

Fishermen' behaviors and perception

The majority of sea turtles entangled in fishing gear appear to be released at sea, and injured turtles often brought onshore by some fishermen were delivered to the local authorities. Therefore, it appears that not all turtles that are landed are destined for consumption. The turtle meat consumption or commercialization by fishermen, who admitted to it, could likely be associated to their socio–economic conditions (impoverished and highly dependent on seafood) or weak port supervision.

The consumption of sea turtle meat likely played an important social role during severe droughts in Cabo Verde in the past, particularly between the 1940s and 1950s during the great hunger and during the war (Merino et al. 2007; Loureiro and Torrão 2008; Martins et al. 2015). Today, turtle meat is not vital for survival and the reasons for turtle meat consumption have changed. The price fetched by the sale of one adult sea turtle (mean = USD128.69 ± 42.90; Hancock et al. 2017) is higher than the minimum salary in Cabo Verde (USD117.26/month), and is determined by turtle size and sex (MADRRM 2008; Hancock et al. 2017), therefore, the sale of sea turtles can generate high and easy income, which may be appealing to fishermen (Hancock et al. 2017). The lack of law enforcement and deficient coastal supervision, especially in remotes ports, hinders the protection of sea turtles. The commercialization of turtle meat is a more recent phenomenon and is restricted to some islands, like Boa Vista, Maio, and Santiago, with the Praia being the principal destination (Merino et al. 2007; MADRRM 2008).

Factors such as the fishermen's socioeconomic status (Béné et al. 2010), sea state, weather conditions, soak time, and the bait used by fishermen (Lopes et al. 2016) were not evaluated in this study, but may be of relevance in future studies. Our results show a significant effect of the number of years fishing (i.e. fisher experience) and the number of fishermen on board a vessel, which both reduced turtle capture rates. This may indicate that fishermen with more experience and larger crew may have more experience and labour power on board a vessel to set gear in such a way that it minimizes incidental capture of sea turtles. Surprisingly however, we found no effect of boat length, fishing on other islands, or engine power, which could be considered to indicate the capacity of larger vessels to fish further and spend more time at sea and thus capture more turtles.

Fishermen who are aware of sea turtle protection laws may be more interested in preserving sea turtles and may make conservation–appropriate decisions. Fishermen with greater fishing experience may have better skills or better fishing gear than younger fishermen, causing the less experienced fishermen to catch more sea turtles and to hide their captured turtles. Differences in behaviour and skills have been observed between older and younger fishermen across various types of fisheries. For instance, McGuinness et al. (2013) observed that, in Norwegian fisheries, younger fishermen had more accidents in fishing vessels than older fishermen. Huchim-Lara et al. (2015) observed that the risk of underwater fishing accidents was higher among younger fishermen because older fishermen had acquired more knowledge of the risks associated with their work over the years. Less experienced fishermen were more focused on the globalized market, which was encouraging them to take more risks to get the ideal catch sizes (Huchim-Lara et al. 2015).

The fishing gear type was not included in the model, because our capture estimates were averaged across all gears and the gear type in our dataset only represents the "main" gear used by fishermen. The limitations of not having gear-specific capture information may have introduced uncertainty into our estimates (Minami et al. 2007; Lucchetti et al. 2017) but these are the first bycatch estimates for a very important sea turtle population, whereby further work may be needed to get gear-specific estimates.

Fishermen's perception of the sea turtle conservation needed in the archipelago appears to have some positive and constructive attitudes. Currently, all islands have local groups working on sea turtle conservation projects who carry out awareness activities in coastal communities (Araújo 2019). We believe that these awareness and environmental education activities are having a positive impact.

The majority of the fishermen consulted agreed with the national sea turtle protection law that classifies these animals as endangered and the natural heritage of Cabo Verde. Unfortunately, some fishermen still reject these laws and may catch more turtles than reported.

Our study has limitations because it depends on the honesty and accuracy of the fishermen (Gilchrist et al. 2005; Turvey et al. 2013; Lucchetti et al. 2017). Sea turtles are protected by law in Cabo Verde, which may have influenced the fishermen's responses (Lucchetti et al. 2017). The fear of being punished for the illegal capture of a protected species may have led to under–reporting the turtle catches in this study (Manzan and Lopes 2015). Therefore, for future studies, we recommend the use of survey methods, such as the randomized response technique proposed by Warner (1965), that aim to remove the potential bias introduced when surveys include sensitive questions such as those related to illegal activities. Arlidge et al. (2020) also presented a protocol which may reduce cognitive biases and more accurately quantify uncertainty in the capture of sea turtle in small-scale fisheries. On-board observation methodology on SSF appears to be unrealistic for a country like Cabo Verde with limited research resources due to the characteristic of the boats, and the dispersed distribution of landing sites. Nevertheless, some studies have shown that, when possible, the installation of remote electronic monitoring cameras on board of SSF boats may be an effective way to monitor catch, being less costly and time consuming (Bartholomew et al. 2018; Glemarec et al. 2020).

This study does not discriminate between intentional and incidental capture by the fishermen interviewed, therefore, we do not know whether the majority of the captures at sea are targeted or incidental catches. Loggerhead turtles occur throughout the coastal region where fishermen were interviewed (Merino et al. 2007; Marco et al. 2011, 2012; Martins et al. 2013; Laloë et al. 2019), and previous studies have suggested that local fishermen often take turtles opportunistically on fishing trips while targeting other species (Cabrera et al. 2000; MADRRM 2008; Hancock et al. 2017). Nevertheless, the intentional capture at sea is poorly known. Quantifying the intentional sea turtle capture around coastal waters from the Archipelago is recommended to develop targeted management strategies.

Management recommendations

The reduction of the fishing effort, and especially the use of passive gears during the loggerhead nesting season in the proximity of the main nesting areas on the islands of Boa Vista, Sal, Maio, Sao Nicolau, Santa Luzia, and Ilhéu de Rombos are strongly recommended (Dancette 2019; Fortes 2019; González et al. 2020).

Furthermore, the implementation of an effective vigilance program at all ports is recommended for Cabo Verde to reduce the intentional capture of sea turtles. In parallel, a programme to collect information on biological (basic parameters) and technical data (fishing gear characteristics) is required, as a baseline for future regulatory, control and monitoring measures (González et al. 2020).

Currently, the use of sea turtles and their by–products is banned in most countries in the world (Humber et al. 2014), and alternative economic services to local communities have been implemented successfully in many places worldwide throughout ecotourism services (Gossling 1999; Pegas et al. 2013; Barrios-Garrido et al. 2019) that demonstrate that live turtles are worth more than dead turtles. These alternative services include employment of locals in nesting beach protection, as tourist guides, as handicraft sellers as well as for community–based homestays (Wilson and Tisdell 2006; Meletis and Campbell 2007; Pegas et al. 2013; Hussin et al. 2015; Marco et al. 2021). The capture of sea turtles by the SSF in Cabo Verde has been occurring for several centuries, therefore, younger fishermen may justifiably claim that it is a traditional subsistence activity of past generations. If this assertion persists, it must be taken into consideration when developing activities to integrate fishermen in sea turtle conservation.

In Cabo Verde, employing people from local communities in sea turtle conservation has become more popular on some islands, such as in Boa Vista, Maio, and Fogo (Marco et al. 2018; Patiño-martinez et al. 2019; Marco et al. 2021; Dinis personal communication). During the 2017 loggerhead turtle nesting season, turtle–watching activities in Boa Vista alone, between tourism agencies and small tour operators, generated approximately 331,993 € excluding taxes (Pereira-Silva 2017). However, the effectiveness and fairness of turtle watching activity in generating income for local communities in the study still needs to be assessed (Hancock et al. 2017; Marco et al. 2021).

There is a need for a bottom–up dialogue with fishermen to identify solutions, modify behaviors, and effect change on the impact of the SSF on sea turtles in Cabo Verde waters. For instance, the marine scientists, conservationists and fishermen from the US, Mexico, and Cuba jointed efforts to share their experience, challenges faced and potential solutions for sea turtle conservation. This initiative contributed to the improvement of their understanding of sea turtle bycatch in Cuba, enhanced the collaboration between the three countries and increased the fishermen motivation to participate in sea turtle research and conservation (Bretos et al. 2017).

Sea turtle conservation stakeholders should work closely with local fishermen and include them in conservation and research programs. This program should include training that allows fishermen to learn about rescuing injured sea turtles brought on board (FAO 2009). Furthermore, a strong relationship could encourage fishermen to report incidental captures and reinforce collaborations with fishermen for robust scientific data on the behaviour and distribution of marine species (Ticheler et al. 1998; Bretos et al. 2017).

During the interviews, some fishermen expressed concerns about the most recent fishing agreement between Cabo Verde and the European Union. This fishing agreement (since 1990 and reinforced in 2007) has been tacitly renewed in 2018 covering a period of five years and permits 71 vessels from the European Union (47 from Spain, 16 from France and 9 from Portugal; European Commission 2019) to fish for tuna and other migratory fish in Cabo Verde's exclusive economic zone. Some fishermen in Cabo Verde consider this fishing agreement highly disruptive to their activity because they believe that there is no supervision or control on the EU catch. Besides competing with national vessels, it is believed that the EU longline fisheries are depleting other marine resources including sea turtles (Melo and Melo 2013). This issue is causing a decreasing acceptance by local fishermen of laws protecting sea turtles. Greater effort is required by Cabo Verde to safeguard its national fisheries and biodiversity and to ensure that international agreements do not undermine its resources and people.

Conclusions

Based on our available information we believe that this is the most comprehensive study evaluating the impact of SSF on sea turtles in the Cabo Verde Archipelago. Even though the annual capture estimates (1.5 sea turtles) per boat is reportedly low, SSF is widespread throughout Cabo Verde with hundreds of active boats, many vessels are not registered, and their overall impact on sea turtles is potentially much greater. Our results provide minimum useful estimates of mortality, help identify ports with a high number of sea turtle captures by the SSF in Cabo Verde, and prioritize areas for further research and for the introduction of management measures (Lucchetti et al. 2017). These results can be used as a national baseline for sea turtle mortality in coastal waters, and will help us interpret the nesting population trends more accurately. Furthermore, these results may provide useful insights into improving the management of sea turtles through the implementation of sustainable activities within local communities. More in–depth work is needed on each island to understand and address this threat and develop appropriate management strategies in collaboration with the fishermen and the government.

Acknowledgements Funding for this project was provided by U.S. Fish and Wildlife Service's Marine Turtle Conservation Fund (Grant Number: F13AP00325), MAVA Foundation (Grant Number: AO1 [17105]) and the FAO—Project CCLME (Grant Number: PO 309880). The authors are grateful to the General Directorate of Fisheries, INDP, the fishing inspectors from Fogo, Santiago, São Nicolau, and Sal, the local NGOs *Caretta caretta* in Santiago and Vitó–Fogo in Fogo, the fishermen's association from São Pedro in São Vicente Island and Palmeiras in Sal Island, the Protected Area office in Sal Island, Herculano Dinis, Sandra Correia, Nelson Lopes, and the fishermen who contributed to this study. In addition, we thank Kátia Lopes and Danielle Awabdi for reviewing and editing the manuscript. Special thanks to the anonymous reviewers for comments and suggestions that substantially improved a previous version of the manuscript as well as the handling editor.

Authors' contributions Samir Martins (SM), Elena Abella (EA) and Adolfo Marco (AM) conceived and designed the experiments; SM, Fernando Rocha, Edson Rodrigues, Ravidson Monteiro and EA collected the data; SM, Leo Clarke and AM performed analyses; SM wrote the first draft of the manuscript and all authors contributed to revisions.

Funding Funding for this project was provided by U.S. Fish and Wildlife Service's Marine Turtle Conservation Fund (Grant Number: F13AP00325), MAVA Foundation (Grant

Number: AO1 [17105]) and the FAO—Project CCLME (Grant Number: PO 309880).

Declarations

Conflict of interest The authors declare no conflict of interest.

References

Alfaro-Shigueto J, Mangel C, Darquea J et al (2018) Untangling the impacts of nets in the southeastern Pacific: rapid assessment of marine turtle bycatch to set conservation priorities in small-scale fisheries. Fish Res 206:185–192. https://doi.org/10.1016/j.fishres.2018.04.013

Araújo S (2019) Relatório da campanha nacional para a conservação das tartarugas marinhas em Cabo Verde. Praia

Arlidge WNS, Alfaro-Shigueto J, Ibanez-Erquiaga B, Mangel JC, Squires D, Milner-Gulland EJ (2020) Evaluating elicited judgments of turtle captures for data-limited fisheries management. Conserv Sci Pract 2:e181. https://doi.org/10.1111/csp2.181

Barrios-Garrido H, Wildermann N, Diedrich A, Hamann M (2019) Conflicts and solutions related to marine turtle conservation initiatives in the Caribbean basin: identifying new challenges. Ocean Coast Manag 171:19–27. https://doi.org/10.1016/j.ocecoaman.2019.01.003

Bartholomew DC, Mangel JC, Alfaro-Shigueto J et al (2018) Remote electronic monitoring as a potential alternative to on-board observers in small-scale fisheries. Biol Conserv 219:35–45. https://doi.org/10.1016/J.BIOCON.2018.01.003

Barton K (2019) MuMIn: multi-model inference. R package version 1.43.15

Belhabib D, Greer K, Pauly D (2018) Trends in industrial and artisanal catch per effort in West African fisheries. Conserv Lett 11:e12360. https://doi.org/10.1111/conl.12360

Béné C, Hersoug B, Allison EH (2010) Not by rent alone: analysing the pro-poor functions of small-scale fisheries in developing countries. Dev Policy Rev 28:325–358. https://doi.org/10.1111/j.1467-7679.2010.00486.x

BOCV (2016) Boteim Oficial da Républica de Cabo Verde - Resolução Nº 29/16 de 16 de Março de 2016 que estabelece o plano executivo bianual de gestão dos recursos de pesca 2016–2017. Praia

BOCV (2018) Boteim Oficial da Républica de Cabo Verde - Decreto Legislativo Nº 1/18 de 21 de Maio de 2018 que estabelece o regime jurídico especial de proteção e conservação das tartarugas marinhas em Cabo Verde. Praia

Bretos F, Ricardo JA, Moncada F et al (2017) Fisheries learning exchanges and sea turtle conservation: an effort between Mexico, Cuba and the U.S. to engage Cuban coastal communities in non-consumptive alternative behaviors. Mar Policy 77:227–230. https://doi.org/10.1016/j.marpol.2016.05.022

Cabrera I, Cejudo D, Lopez-Jurado LF (2000) Human predation on marine turtles in the archipelago of Cape Verde, western Africa. In: Kalb K, Wibbels T (eds) Proceedings of the nineteenth annual symposium on sea turtle conservation and biology. NOAA Tech Memo NMFSSEFSC-443, South Padre Island, Texas, p 217

Carruthers EH, Neis B (2011) Bycatch mitigation in context: Using qualitative interview data to improve assessment and mitigation in a data-rich fishery. Biol Conserv 144:2289–2299. https://doi.org/10.1016/J.BIOCON.2011.06.007

Casale P, Marco A (2015) *Caretta caretta* (North East Atlantic subpopulation), loggerhead turtle. IUCN Red List Threat Species 8235:15

Chuenpagdee R, Jentoft S (2018) Transforming the governance of small-scale fisheries. Marit Stud 17:101–115. https://doi.org/10.1007/s40152-018-0087-7

Cocks K, Torgerson DJ (2013) Sample size calculations for pilot randomized trials: a confidence interval approach. J Clin Epidemiol 66:197–201. https://doi.org/10.1016/j.jclinepi.2012.09.002

Coelho R, Santos MN, Fernandez-carvalho J, Amorim S (2015) Effects of hook and bait in a tropical northeast Atlantic pelagic longline fishery: part I—Incidental sea turtle bycatch. Fish Res 164:302–311. https://doi.org/10.1016/j.fishres.2014.11.008

European Commission (2019) Cape Verde Fisheries partnership agreement. In: Cape Verde Fish. Partnersh. Agreem. https://ec.europa.eu/fisheries/cfp/international/agreements/cape_verde. Accessed 8 Jun 2019

Cozens J, Taylor H (2011) Nesting activity of the loggerhead sea turtle *Caretta caretta* (Linnaeus, 1758) on Maio, Cape Verde Islands. Zool Caboverdiana 2:62–70

Dancette R (2019) Growing vulnerability in the small-scale fishing communities of Maio, Cape Verde. Marit Stud 18:205–223. https://doi.org/10.1007/s40152-019-00137-2

DGRM (2014) Medidas de gestão do esforço de pesca artesanal em Cabo Verde. Praia

FAO (2009) Guidelines to reduce sea turtle mortality in fishing operations. FAO Fisheries and Aquaculture Department, Rome

Fortes D (2019) Assessment of economic viability of the artisanal fisheries in Cabo Verde: recommendations for improvement. United Nations University Fisheries Training Program, Iceland. Final project. http://www.unuftp.is/static/fellows/document/Delvis18prf.pdf

Fretey J (2001) Biogeography and conservation of marine turtles of the Atlantic coast of Africa

Gilchrist G, Mallory M, Merkel F (2005) Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. Ecol Soc 10:20. https://doi.org/10.2307/26267752

Glemarec G, Kindt-Larsen L, Lundgaard LS, Larsen F (2020) Assessing seabird bycatch in gillnet fisheries using electronic monitoring. Biol Conserv 243:108461. https://doi.org/10.1016/j.biocon.2020.108461

González JA, Monteiro C, Correia S et al (2020) Current and emerging small-scale fisheries and target species in Cabo Verde, with recommendations for pilot actions favouring sustainable development. Cybium Int J Ichthyol 44:355–371. https://doi.org/10.26028/cybium/2020-444-006

Gossling S (1999) Ecotourism: a means to safeguard biodiversity and ecosystem functions? Ecol Econ 29:303–320. https://doi.org/10.1016/S0921-8009(99)00012-9

Guebert FM, Barletta M, da Costa MF (2013) Threats to sea turtle populations in the Western Atlantic: poaching and mortality in small-scale fishery gears. J Coast Res 65:42–47. https://doi.org/10.2112/SI65-008.1

Hancock JM, Furtado S, Elsy Merino S et al (2017) Exploring drivers and deterrents of the illegal consumption and trade of marine turtle products in Cape Verde, and implications for conservation planning. Oryx 51:428–436. https://doi.org/10.1017/S0030605316000107

Huchim-Lara O, Salas S, Chin W et al (2015) Diving behavior and fishing performance: the case of lobster artisanal fishermen of the Yucatan coast, Mexico. UHT J 42:285–296

Humber F, Godley BJ, Broderick AC (2014) So excellent a fishe: a global overview of legal marine turtle fisheries. Divers Distrib 20:579–590. https://doi.org/10.1111/ddi.12183

Hussin R, Kunjuraman V, Weirowski F (2015) Work transformation from fisherman to homestay tourism entrepreneur: a study in Mantanani Island Kota Belud, Sabah, East Malaysia. J Kemanus 13:1675–1930

INDP (1993) Boletim estatístico. Dados sobre a pesca artesanal, pesca industrial, conservas e exportação. Mindelo, Cabo Verde

INE (2020) Cabo Verde, Anuário Estatístico 2019. Praia

Koch V, Nichols WJ, Peckham H, de la Toba V (2006) Estimates of sea turtle mortality from poaching and bycatch in Bahia Magdalena, Baja California Sur, Mexico. Biol Conserv 128:327–334. https://doi.org/10.1016/j.biocon.2005.09.038

Lagueux CJ, Campbell CL, Strindberg S (2017) Artisanal green turtle (*Chelonia mydas*) fishery of Caribbean Nicaragua: II. Characterization and trends in size, sex, and maturity status of turtles killed, 1994–2011. Mar Biol 164:60. https://doi.org/10.1007/s00227-017-3092-2

Laloë J-OO, Cozens J, Renom B et al (2019) Conservation importance of previously undescribed abundance trends: increase in loggerhead turtle numbers nesting on an Atlantic island. Oryx 54:1–8. https://doi.org/10.1017/S0030605318001497

Lewison RL, Crowder LB, Read AJ, Freeman SA (2004) Understanding impacts of fisheries bycatch on marine megafauna. Trends Ecol Evol 19:598–604. https://doi.org/10.1016/j.tree.2004.09.004

Lewison RL, Crowder LB, Wallace BP et al (2014) Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots. Proc Natl Acad Sci USA 111:5271–5276. https://doi.org/10.1073/pnas.1318960111

Lopes K, Passos L, Rodrigues JG et al (2016) Sea turtle, shark and dolphin bycatch rates by artisanal and semi-industrial fishers in the Island of Maio, Cape Verde. Chelonian Conserv Biol 15:279–288. https://doi.org/10.2744/CB-1213.1

Loureiro ND, Torrão MM (2008) Homens e tartarugas marinhas. Seis séculos de história e histórias nas ilhas de Cabo Verde. Anais Hist Além Mar 2:37–78

Lucchetti A, Vasapollo C, Virgili M (2017) An interview-based approach to assess sea turtle bycatch in Italian waters. PeerJ 5:e3151. https://doi.org/10.7717/peerj.3151

Lum LL (2006) Assessment of incidental sea turtle catch in the artisanal gillnet fishery in Trinidad and Tobago, West Indies. Appl Herpetol 3:357–368. https://doi.org/10.1163/157075406778905081

MADRRM (2008) Plano nacional para a conservação das tartarugas marinhas em Cabo Verde. Praia

Mancini A, Koch V, Seminoff JA, Madon B (2012) Small-scale gill-net fisheries cause massive green turtle *Chelonia mydas* mortality in Baja California Sur, Mexico. Oryx 46:69–77. https://doi.org/10.1017/S0030605310001833

Manzan MF, Lopes PFM (2015) Fishers' knowledge as a source of information about the estuarine dolphin (*Sotalia guianensis*, van Bénéden, 1864). Environ Monit Assess 187:4096. https://doi.org/10.1007/s10661-014-4096-8

Marco A, Abella-Pérez E, Monzón-argüello C et al (2011) The international importance of the archipelago of Cape Verde for marine turtles, in particular the loggerhead turtle *Caretta caretta*. Zool Caboverdiana 2:1–11

Marco A, Abella E, Liria-Loza A et al (2012) Abundance and exploitation of loggerhead turtles nesting in Boa Vista island, Cape Verde: the only substantial rookery in the eastern Atlantic. Anim Conserv 15:351–360. https://doi.org/10.1111/j.1469-1795.2012.00547.x

Marco A, Martins S, Abella E, Patiño-martinez J (2018) Potential causes for an important and hopeful increase in sea turtle nesting in Cabo Verde in 2018. Afr Sea Turt Newsl 10:4–8

Marco A, Martins S, Martín-Rábano A, Lopes S, Clarke LJ, Abella E (2021) Risk assessment of wildlife-watching tourism in an important endangered loggerhead turtle rookery. Endang Species Res 45:195–207. https://doi.org/10.3354/esr01130

Martins S, Rocha F, Rodrigues E et al (2015) The use of sea turtles in traditional medicine in the Cape Verde Archipelago, West Africa. Afr Sea Turt Newsl 4:12–15

Martins S, Soares F, Ribeiro E et al (2013) Importance of the island of Maio (Cape Verde) for current and future loggerhead conservation in the Eastern Atlantic. In: Tucker T, Belskis L, Panagopoulou A et al. (eds) Proceedings of the thirty-third annual symposium on sea turtle biology and conservation. NOAATechnical Memorandum, Baltimore, USA, p 106

McGuinness E, Aasjord HL, Utne IB, Holmen IM (2013) Injuries in the commercial fishing fleet of Norway 2000–2011. Saf Sci 57:82–99. https://doi.org/10.1016/j.ssci.2013.01.008

Meletis ZA, Campbell LM (2007) Call it consumption! re-conceptualizing ecotourism as consumption and consumptive. Geogr Compass 1:850–870. https://doi.org/10.1111/j.1749-8198.2007.00048.x

Melo J, Melo T (2013) Interviews with fishers suggest Eurpean longlining threatens sea turtle population in Cape Verdean waters. Mar Turt Newsl 138:18

Mendes VS (2010) Contribuição para análise do estado de conservação da tartaruga marinha Caretta caretta (Linnaeus, 1758) no Tarrafal de Santiago, Cabo Verde (2010). São Vicente

Merino SE, Correia S, Cruz I, Correia MA (2007) O Arquipiélago de Cabo Verde e a conservação das tartarugas marinhas. ambientalMENTEsustentable 4:117–123

MIEM MDI-E (2011) Relatório de principais resultados do censo geral da frota de pesca artesanal e industrial/semi-industrial ano de 2011. Mindelo, Cabo Verde

Minami M, Lennert-Cody CE, Gao W, Román-Verdesoto M (2007) Modeling shark bycatch: the zero-inflated negative binomial regression model with smoothing. Fish Res 84:210–221. https://doi.org/10.1016/j.fishres.2006.10.019

Monzón-argüello C, López-Jurado LF, Rico C et al (2010a) Evidence from genetic and Lagrangian drifter data for transatlantic transport of small juvenile green turtles. J Biogeogr 37:1752–1766. https://doi.org/10.1111/j.1365-2699.2010.02326.x

Monzón-Argüello C, Rico C, Marco A et al (2010b) Genetic characterization of eastern Atlantic hawksbill turtles at a foraging group indicates major undiscovered nesting populations in the region. J Exp Mar Bio Ecol 387:9–14. https://doi.org/10.1016/j.jembe.2010.03.004

Moore JE, Cox TM, Lewison RL et al (2010) An interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries. Biol Conserv 143:795–805. https://doi.org/10.1016/j.biocon.2009.12.023

Neves DRR, Conceição EEP (2009) Contribuição para análise do estado de conservação da tartaruga marinha Caretta caretta (Linnaeus, 1758) na ilha de São Nicolau - Cabo Verde (2008). São Vicente

Patiño-martinez J, Dos PL, Dos RE, Moreno R (2019) Integrating local leaders in efforts to improve biodiversity conservation. Afr Sea Turt Newsl 12:4–7

Peckham S, Maldonado Diaz D, Koch V et al (2008) High mortality of loggerhead turtles due to bycatch, human consumption and strandings at Baja California Sur, Mexico, 2003 to 2007. Endanger Species Res 5:171–183. https://doi.org/10.3354/esr00123

Pegas FDV, Coghlan A, Stronza A, Rocha V (2013) For love or for money? Investigating the impact of an ecotourism programme on local residents' assigned values towards sea turtles. J Ecotourism 12:90–106. https://doi.org/10.1080/14724049.2013.831099

Pereira-Silva M (2017) Relatório da campanha de tartarugas marinhas 2017. Sal Rei

Poonian CNS, Hauzer M, Allaoui A et al (2009) Rapid assessment of sea turtle and marine mammal bycatch in the Union of the Comoros. West Indian Ocean J Mar Sci. https://doi.org/10.4314/wiojms.v7i2.48279

R Core Team (2020) R: A language and environment for statistical computing

Rocha PRPR, Melo T, Rebelo R, Catry P (2015) A Significant nesting population of loggerhead turtles at the Nature Reserve of Santa Luzia, Cabo Verde. Chelonian Conserv Biol 14:161–166. https://doi.org/10.2744/CCB-1143.1

Salas S, Chuenpagdee R, Seijo JC, Charles A (2007) Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. Fish Res 87:5–16. https://doi.org/10.1016/J.FISHRES.2007.06.015

Soykan C, Moore JE, Zydelis R et al (2008) Why study bycatch? An introduction to the theme section on fisheries bycatch. Endanger Species Res 5:91–102. https://doi.org/10.3354/esr00175

Taylor H, Cozens J (2010) The effects of tourism, beachfront development and increased light pollution on nesting loggerhead turtles. Zool Caboverdiana 1:100–111

Ticheler HJ, Kolding J, Chanda B (1998) Participation of local fishermen in scientific fisheries data collection: a case study from the Bangweulu Swamps, Zambia. Fish Manag Ecol 5:81–92

Turvey ST, Risley CL, Moore JE et al (2013) Can local ecological knowledge be used to assess status and extinction drivers in a threatened freshwater cetacean? Biol Conserv 157:352–360. https://doi.org/10.1016/j.biocon.2012.07.016

Varo-Cruz N, Cozens J, Liria-loza A, Fretey J (2011) New records of the olive ridley sea turtle *Lepidochelys olivacea* (Eschscholtz, 1829) from the Cape Verde Islands. Zool Caboverdiana 2:53–61

Venables WN, Ripley BD (2002) Modern applied statistics with S, 4th edn. Springer, New York

Wallace BP, Dimatteo AD, Bolten AB et al (2011) Global conservation priorities for marine turtles. PLoS ONE 6:e24510. https://doi.org/10.1371/journal.pone.0024510

Wallace BP, Kot CY, Dimatteo AD et al (2013) Impacts of fisheries bycatch on marine turtle populations worldwide: toward conservation and research priorities. Ecosphere. https://doi.org/10.1890/ES12-00388.1

Warner SL (1965) Randomized response: a survey technique for eliminating evasive answer bias. J Am Stat Assoc 60:63–69. https://doi.org/10.2307/2283137

Wilson C, Tisdell C (2006) Conservation and economic benefits of wildlife-based marine tourism: sea turtles and whales as case studies. Hum Dimens Wildl 8:49–58. https://doi.org/10.1080/10871200390180145

Wirtz P, Brito A, Falcon JM et al (2013) The coastal fishes of the Cape Verde Islands—new records and an annotated check-list. Spixiana 36:113–142

Witherington BE, Frazer NB (2002) Social and economic aspects of sea turtle conservation. In: Lutz PL, Musick JA, Wyneken J (eds) The biology of sea turtles, vol 2. CRC Press, Boca Raton, Florida