

Assessing Sea Turtle, Seabird and Shark bycatch in Artisanal, Semi-industrial
and Industrial of Fisheries in the Cabo Verde Archipelago

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List of abbreviations used

BO – Boletim Oficial

CITES – Convention on The International Trade in Endangered Species of Flora and Fauna

DGRM – Direção Geral dos Recursos Marinhos

DNEM – Direção Nacional da Economia Marítima

EEZ – Exclusive economic zone

EU – European Union

FAO – Food and Agriculture Organization of the United Nations

GDP – Gross Domestic Product

IMar – Instituto do Mar

IUCN – International Union for Conservation of Nature

INDP – Instituto Nacional de Desenvolvimento das Pescas

MAAP – Ministério de Agricultura Alimentação e Pesca

MAHOT – Ministério de Agricultura Habitação Ordenamento de Território

NGO – Non-Governmental Organizations

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Abstract

Bycatch mortality, or the incidental catch of non-target species in fishing gear, is a major cause of the rapid declines of marine megafauna such as sea turtles, seabirds and elasmobranchs (sharks and rays). The island nation of Cabo Verde hosts an important diversity of fisheries within its Exclusive Economic Zone but the effect of bycatch on its diverse marine megafauna is poorly known. I assess and compare the bycatch of sea turtles, seabirds and sharks in different fishing gears from artisanal, semi-industrial and industrial vessels based on fisher interviews conducted at five Cabo Verde islands. Among all interviews (n = 94 fishers, representing 160 fishery-specific responses), almost all fishers reported shark bycatch (91%), and high proportions of fishers also reported turtle (73%) and seabird (66%) bycatch. Fishers reported (100%, n= 40 and 3 of respondents reported bycatch on handline) of bycatch of loggerhead *Caretta caretta* on artisanal and semi-industrial handline respectively, and fishers working on industrial vessels reported regular turtle bycatch (mainly leatherback turtles *Dermochelys coriacea*) using longline fishing gear (89%, n = 19), followed by loggerhead *Caretta caretta* (63%, n=19). Seabird bycatch, mainly Cape Verde shearwaters *Calonectris edwardsi*, was reported by artisanal and semi-industrial fishers using handlines (96% and 83%, n = 55 and 6 of respondents reported bycatch on handline), followed by industrial vessels using longline fishing gear (100%, n = 7 of respondents reported bycatch on longline). All longline fishers from industrial vessels reported mako shark *Isurus oxyrinchus* bycatch (100%, n = 22), while artisanal and semi-industrial fishers mainly reported bycatch of smooth hound *Mustelus mustelus* and nurse sharks *Ginglymostoma cirratum* on handlines (68% and 80%, n = 63 and 5 of respondents reported bycatch on handline). This study underlines high levels of turtle, seabird and shark bycatch in Cabo Verde and highlights the need for management actions as well as the development of an observer program to increase our understanding of bycatch levels and their impact as well as inform future bycatch management and mitigation measures.

Introduction

Bycatch mortality, or the incidental catch of non-target species in fishing gear, is a major cause of the rapid population declines of many marine species around the world (Tasker *et al.*, 2000; Lum, 2006; Moore *et al.*, 2010, Tuck *et al.*, 2011; Croxall *et al.*, 2012; Regular *et al.*, 2013). In recent decades, the bycatch of marine megafauna (e.g., turtles, seabirds, marine mammals and elasmobranchs – sharks and rays) has become a cause of concern for the management and conservation of marine resources (Hall *et al.*, 2000; Soykan *et al.*, 2008). When bycatch occurs, accidentally caught species with economic value may be kept, compensating for the expense of damaged or lost materials, while species with no commercial value are usually discarded at sea (Cook, 2003).

Many marine bycatch species such as turtles, seabirds, marine mammals and sharks and rays (hereafter referred to as ‘shark’) are characterized by long life spans, late maturity and low reproductive rates, making them especially susceptible to additional mortality (FAO, 1999a, 1999b; Lewison *et al.*, 2004; FAO, 2005; Dulvy *et al.*, 2008; Read, 2008; Gilman and Lundin, 2010; Wallace *et al.*, 2010; Senko *et al.*, 2013). Migratory species are particularly at risk because they traverse national boundaries and occupy a large area of the oceans to forage or reproduce, exposing them to multiple fisheries (Coelho *et al.*, 2015). Many fisheries capture multiple species and the risk of bycatch can depend on the animal’s biology, life stage, its distribution and interaction with fisheries and different gear types (Wallace *et al.*, 2008; Moore *et al.*, 2009; Bjorkland, 2011).

Turtles are particularly susceptible to bycatch. Among the seven species of marine turtles, six are listed as threatened, and one as Data Deficient (IUCN Red List, 2019). Turtle populations have decreased mainly through hunting both in the marine environment and at their nesting sites (Wallace *et al.*, 2010; Coelho *et al.*, 2015). Fisheries bycatch, and other threats (e.g. plastic

ingestion, entanglement, light pollution and climate change) exacerbate these decreases (Pauly *et al.*, 2005; Brander, 2008; Gilman *et al.*, 2009). While hunting mostly affects females on nesting beaches (López-Jurado *et al.*, 2000; Marco *et al.*, 2008, 2010, 2012), males are also targeted at sea due to the popular belief of aphrodisiacal power of the males' genitals (Merino *et al.*, 2007; Martins, 2017). Turtles are especially susceptible to pelagic fishing gear such as pelagic longlines, purse seine and driftnets (Lewison *et al.*, 2004; Gilman *et al.*, 2006, 2009; Lewison and Crowder, 2007;), and coastal gear such as inshore trawls, gillnets and pound nets (Álvarez de Quevedo *et al.*, 2010; Gilman *et al.*, 2010).

Seabirds are also distinctly threatened by fishery activities through bycatch and the overexploitation of their prey (Tasker *et al.*, 2000; Croxall *et al.*, 2012). Although it is difficult to accurately evaluate the direct mortality rate linked to fishery activities (Uhlmann *et al.*, 2005), hundreds of thousands of birds are believed to die annually directly or indirectly because of fishery activities (Zydelis *et al.*, 2009; Brothers *et al.*, 2010, Anderson 2011). In a recent quantitative assessment of the threats affecting seabirds, bycatch was ranked the second most important threat to this group because it impacts nearly a third of all seabird species and has the greatest average impact (Anderson *et al.*, 2011). Seabirds are attracted to fishing vessel discards, bait and offal, and can become accidentally entangled in fishing gear, hooked on longlines or collide with warp cables. While most by-caught seabirds are discarded, in some isolated localities where there is still a demand for seabird meat, they can be kept for consumption (Melo & Melo, 2013). Some species of albatrosses, petrels and shearwaters are so affected by longline fisheries that their populations are decreasing to unsustainable levels because of bycatch alone, even without the numerous other threats such as invasive predators and climate change that also affect these species (Lewison & Crowder, 2003).

Sharks are also highly susceptible to bycatch, although they are still targeted intentionally more than is generally the case for turtles and seabirds. Longline fisheries have particularly large

impacts on shark populations and are believed to be one of the main drivers for the decline in pelagic sharks worldwide (Cortés *et al.*, 2010). Because the price for shark products, particularly their fins, is extremely high in Asian markets, several populations are experiencing drastic declines and more than a quarter of shark species are considered to be threatened globally (Dulvy *et al.*, 2008; Ferretti *et al.*, 2010; Dulvy *et al.*, 2014). Although many countries now prohibit the capture of sharks exclusively for their fins, the ratio of sharks to target species landed is still over 40% in some fisheries (notably pelagic longlines) (Oliver *et al.*, 2015). However, shark bycatch is rarely recorded at the species level, making it difficult to estimate annual mortality and the direct effects of bycatch on many shark populations (Bonfil, 1994; Clarke, 2006).

In the Cabo Verde archipelago, relatively little is known about the bycatch of these marine megafauna. The island nation has five of the seven species of sea turtles, nine breeding seabird species and over 100 species of elasmobranchs (sharks and ray), yet few studies have examined the impact of fisheries on these species. Lopes *et al.* (2016) assessed turtle and shark bycatch by interviewing 109 artisanal (handline, free diving, and scuba diving) and 30 semi-industrial (purse seine and surface longline) fishers from Maio and Santiago and found that 32% of fishers reported turtle bycatch and 71% shark bycatch. Melo & Melo (2013) concluded that European longline vessels threaten sea turtle and shark populations in Cabo Verde waters, based on interviews with 17 Cabo Verde fishers who worked seasonally in the international fishing fleet. However, neither of these studies assessed the spatio-temporal variability in bycatch, differences in bycatch rates related to gear types, nor the relative impacts of artisanal, semi-industrial or industrial fishing. Furthermore, to date, there has been no assessment of seabird bycatch in Cabo Verde waters.

Globally, most studies of megafauna bycatch have focused on the impacts of industrial fisheries (Pauly, 2006; Soykan *et al.*, 2008; Moore *et al.*, 2010). However, artisanal fisheries are

widespread, accounting for over 95% of the world's fishers (Pauly, 2006). Recent studies suggest that artisanal fisheries potentially have a significant negative impact on these megafaunal taxa (Lee Lum, 2006; Peckham *et al.*, 2007, 2008; Jaramillo-Legorreta *et al.*, 2007; Mangel *et al.*, 2010), so the impact of such fisheries needs to be assessed (Moore *et al.*, 2010).

The goal of my study was to investigate how turtles, seabirds and sharks in Cabo Verde waters interact with different fishing gears and vessel types, and how this changes seasonally and between islands. To do this, I reviewed the archipelago's general fishery features using data from the Instituto Nacional de Desenvolvimento das Pescas (INDP), currently designated as the Instituto do Mar (IMar). Then, I used structured interviews to address my specific objectives to: (1) characterize fishing gear and bait types and determine the fishing effort of artisanal, semi-industrial and industrial fisheries across the archipelago; (2) assess which fishing gear, bait, areas, times of year and times of day have the highest bycatch rates; and (3) assess which species have the highest bycatch rates in the various fishery sectors. This study provides insights into the sustainability of current fishing activity in Cabo Verde and can help to inform future conservation initiatives and, where necessary, help managers to devise effective mitigation measures.

Methods

Study area

The Republic of Cabo Verde, a former Portuguese colony which gained independence in 1975, consists of ten islands and 13 islets of volcanic origin. The country is situated between 14° 50'N and 17° 20'N and 22° 40'W and 25° 30'W, 750 km off West Africa and has a land area of 4,030 km² (FAO STAT 2013). Nine islands are inhabited, with a human population of 535,000 (FAO STAT, 2018). The islands are separated into two groups: the Barlavento islands (Santo Antão, São Vicente, Santa Luzia (uninhabited), São Nicolau, Sal and Boa Vista) and the Sotavento

islands (Maio, Santiago, Fogo and Brava) (Fig. 1). The uninhabited islets are often used by fishers for overnight encampments (Meintel, 1984; Silva, 2009). The islands have an Exclusive Economic Zone (EEZ) of 804 694 km².

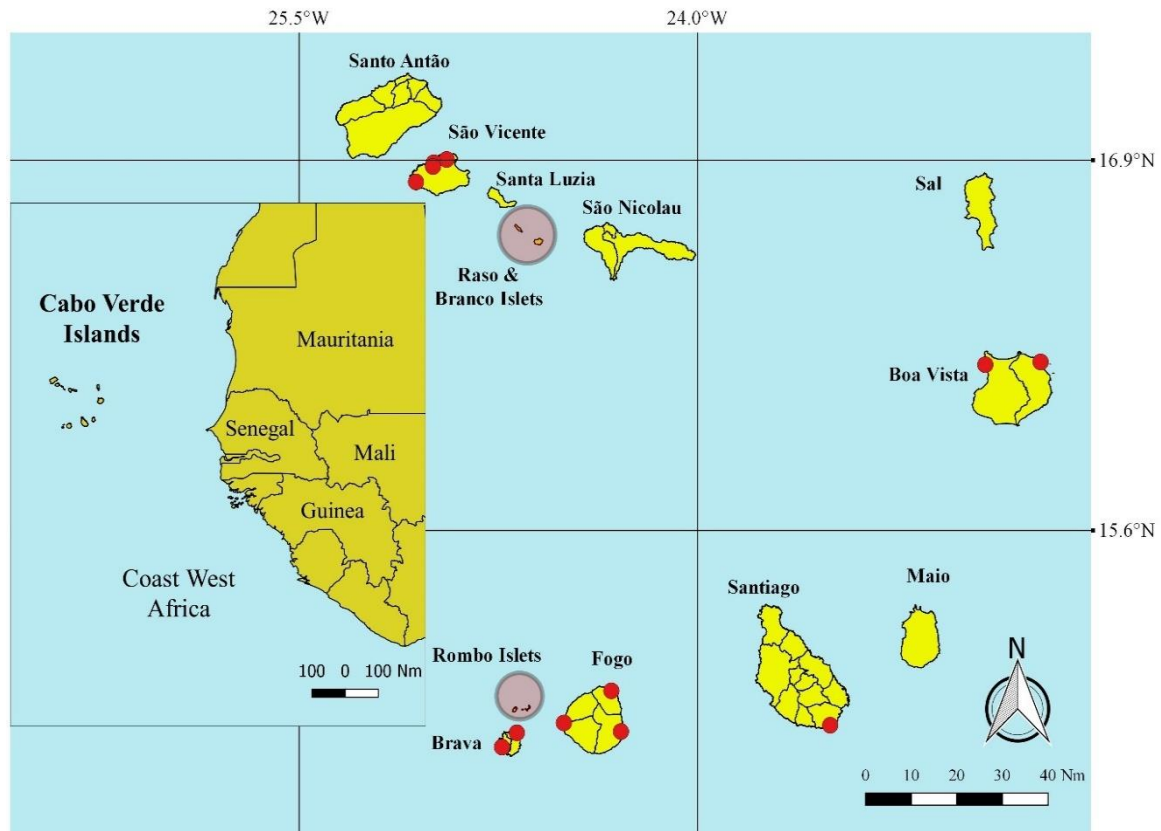


Fig. 1 The Cabo Verde archipelago. Red points indicate the fishing ports and landing sites where the interviews took place on the surveyed islands of São Vicente, Boa Vista, Santiago, Fogo and Brava; Ellipse show the Islets (Raso and Branco, Rombo) and the black lines within the Islands are the municipal boundaries.

Review of Cabo Verde fisheries

Until the early 1980s, there were few studies of the Cabo Verde fishing industry (MAAP, 2004). However, in 1981, a national agency began to collect data on fishing effort and landings (Monteiro, 2002; Stobberup and Erzini, 2006). Currently, the entity responsible for recording fishery catch and effort data is the IMar. This agency is part of the strategy aimed at the sustained development of research and technological development activities in the ‘ocean

economy' according to decree N°40/2019, September 24 (IMar, 2019), replacing the National Institute for Fisheries Development (INDP) (Trindade *et al.*, 2013), which was formed in 1992.

In the island nation of Cabo Verde, fisheries are an important source of employment throughout the archipelago, and contribute fundamentally to the country's development (Silva, 2009). Gonzalez *et al.* (2009) suggested that fisheries employ about 2.1% of the population (5.2% of the active population). Although some studies estimate that fisheries contribute only 1-2% of the Gross Domestic Product (GDP) (Almeida *et al.*, 2003), the FAO estimates this value to be 3.9%, highlighting the economic importance of the fisheries sector (Ministry of Infrastructure Transport and Sea, 2008).

Despite the islands' large EEZ and diversity in fishing resources, fish biomass is relatively small. This is largely due to the small area of shallow coastal waters (5,394 km²), linked to the limited extension of the islands' platform due to their volcanic origin (Bravo de Laguna, 1985; Menezes *et al.*, 2004). Other factors that contribute to the modest fish biomass include the depth of these oceanic waters with well stratified surface layers that limit vertical nutrient exchange.

The fishing fleet in Cabo Verde can be divided into two groups: domestic (artisanal and semi-industrial fisheries) and foreign (industrial fisheries) (INDP, 2008, 2009; MegaPesca, 2010). The small-scale artisanal fleet comprises of boats ranging from 3.5 to 8 m in length and 1.5 to 2.5 m wide which are motorized, or powered by sail or paddles and crewed by 2–5 fishers (INDP, 2008; DNEM, 2016). Target species are mainly tuna, along with some demersal fish which are caught with hook and line, lobster and conch which are caught by scuba diving, and small pelagic fish caught with purse seines, gillnets and beach nets (Almeida *et al.*, 2003; Menezes *et al.*, 2004; DNEM, INDP, 2016; Chuenpagdee *et al.*, 2006; Stocks *et al.*, 2019) (Table 1). Another, less frequent type of fishing is dredging for whelks (Menezes *et al.*, 2014).

Products from artisanal fisheries are traded almost exclusively on the domestic market. Most fish are sold fresh, with only 3% dried, salted or preserved in brine. Marketing is done by fishmongers in municipal markets or sold door to door.

Table 1. Summary of major gear types and associated target species by fisheries operating from the Cabo Verde archipelago.

Fisheries	Target species
Artisanal (hook and line)	Tunas and other large pelagic and demersal fish
Artisanal (Scuba)	Lobster, conch
Artisanal (purse seine, gillnets and beach nets)	Small pelagic
Semi-industrial (hand line, tuna pole fishing)	Tunas and other large pelagic and demersal fish
Semi-industrial (purse seine)	Small pelagic
Semi-industrial (traps)	Lobster
Industrial (surface longline)	Tunas
Industrial (purse seine)	Tunas and small pelagic fish

There is a strong tradition of artisanal fishing throughout the archipelago. It is a major source of employment (Baptista *et al.*, 2006), livelihood and animal protein (Tvedten and Hersoug, 1992). In most cases, fishers work exclusively in fishing, but there are also some part-time fishers who switch from agriculture during periods of drought. Fishers who work exclusively in fishing usually come from a family where the profession is passed down from parent to child,

where vessels belong to families (Almeida *et al.*, 2003). In 2018, 5,078 fishers operated 1,588 small boats, landing 4,174 tonnes of fish. This effort and catch shows little change over the last two decades (National Directorate of Maritime Economy – NDME; INDP, 2018; Fig. 2).

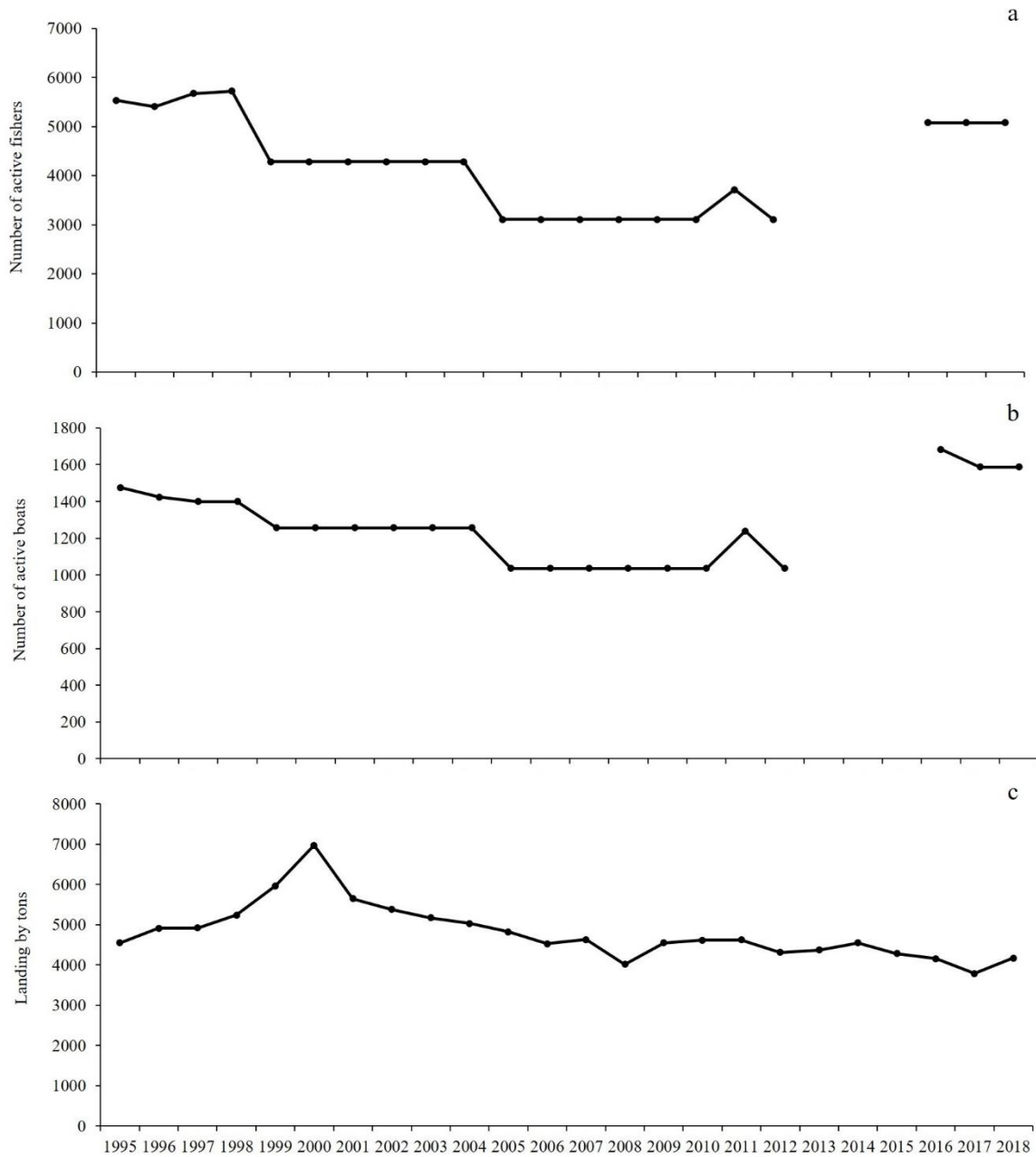


Fig. 2 Summary of annual artisanal fishery landings from 1995-2018 in the Cabo Verde archipelago in relation to changes in the number of a) fishers; b) boats, but no data available of active fishers and boats from 2013 to 2016 and c) total landings (data source: INDP).

The semi-industrial and industrial fishing fleet operating in Cabo Verde is composed of so-called “large-scale” vessels, with lengths ranging from 8 to 28 m, with crews of 5 to 14 fishers (Fonseca, 2000; INDP, 2000; MegaPesca, 2004, 2010; DNEM, INDP, 2016). Semi-industrial vessels mainly target large pelagic and demersal fish using handlines and tuna pole fishing, small pelagic species with purse seine, and lobster using traps (MAAP, 2004; Silva, 2009; Table 1). Before 1991, tuna landings represented about 80% of the total domestic semi-industrial catch. However, the introduction of purse seine vessels in 1992 targeting small pelagic fish reduced the relative importance of tuna landings to around 40% by 1998 (Fonseca, 2000).

The foreign industrial fleet operating in the Cabo Verde EEZ mainly fish with surface longlines, tuna pole fishing and purse seines (Santos *et al.*, 2013), and the main target species are tunas, and small pelagic fish (Silva, 2009; Table 1). Industrial fleets typically use a single gear type to target a defined set of species (Chuenpagdee *et al.*, 2006; Stocks *et al.*, 2019). Nationally, only one large vessel, ranging up to 20 m in length operates in Cabo Verde's waters, and the others are semi-industrials engaged in small pelagic, demersal and tuna fisheries (Report, DGRM, 2018). According to law decree N° 02/2015, foreign vessels may only operate in Cabo Verde waters under international agreements with the flag or registration State or the organizations representing them, except in exceptional cases duly authorized by the member of Government responsible for fisheries (Report, DGRM, 2018).

A fisheries partnership agreement between the European Community and the Republic of Cabo Verde allows EU vessels to fish in Cabo Verdean waters and is part of the tuna network fisheries agreements in West Africa. The foreign fleet included in these agreements are mainly from the European Union (Spain, France and Portugal), Senegal and Japan (Almeida *et al.*, 2003; Report, DGRM, 2018), although many of the crew are Cabo Verdean fishers. The most recent license agreement, signed in October 2018, is valid for 5 years and offers EU vessels an

annual quota of 8,000 tonnes of tuna and other related species. This agreement restricts vessels to fish beyond 12 nautical miles with tuna poles and from 18 nautical miles with purse seines and longlines. Catches from industrial fisheries are processed and distributed in national markets and also exported. Data from INE, Instituto Nacional de Estadística, reported an export of a corresponding part of fishery products of the order of 13, 24, 24, and 17 tonnes per year from 2014 to 2017 (FAO, 1997; INDP, 2009, 2012, 2018).

From 2014 to 2017 the number of foreign vessels licensed increased by 15%. Catches in Cabo Verde waters were taken by 8, 10, 14 and 13 tuna pole vessels, 26, 31, 36 and 36 tuna seiner vessels and 27, 28, 33 and 39 surface longliners respectively in 2014, 2015, 2016 and 2017 (Report, DGRM, 2018) (Table 2).

Table 2. Numbers of licenses granted to foreign industrial fishing vessels to operate in Cabo Verde waters from 2014-2017 (Source: Directorate General of Marine Resources, 2018).

Vessel type	Country	2014	2015	2016	2017
Tuna pole and line	Spain	7	7	7	7
	France	1	1	1	1
	Portugal	-	-	1	-
	Senegal	0	2	5	5
Total tuna pole and line		8	10	14	13
Tuna purse seiner	Spain	13	12	12	11
	France	9	9	11	10
	Senegal	-	3	3	5
Albacore purse seiner		4	7	10	10
Total purse seiner		26	31	36	36
Surface longliners	Spanish	9	7	11	16
	Portuguese	-	2	2	0
	Japanese	18	19	20	23
Total longliners		27	28	33	39
Total industrial fleet		61	69	83	88

Cabo Verde sea turtles, seabirds and sharks

Cabo Verde waters are home to five of the seven species of sea turtles that may be affected by bycatch (López-Jurado *et al.*, 2000a; Marco *et al.*, 2011; Lopes *et al.*, 2016; Martins *et al.*, 2015). The most common species is the loggerhead turtle *Caretta caretta* (Endangered), which breeds on Cabo Verde sandy beaches, representing the third largest loggerhead nesting population worldwide (Marco *et al.*, 2011; Martins *et al.*, 2015). Hawksbill turtles *Eretmochelys imbricata* (Critically Endangered) and green turtles *Chelonia mydas* (Endangered) also feed in the archipelago's waters (Marco *et al.*, 2011; Martins *et al.*, 2015), and occasionally nest on Maio and Boavista Island (Lopes *et al.*, 2016; Martins, 2017). Leatherback turtles *Dermochelys coriacea* (Critically Endangered) and olive ridley *Lepidochelys olivacea* (Vulnerable) occasionally migrate through the waters of the archipelago (Marcos *et al.*, 2011).

Cabo Verde is also home to several seabird species that may be impacted by fishing operations. These include four endemic species: Cape Verde shearwater *Calonectris edwardsii*, Cape Verde petrel *Pterodroma feae*, Cape Verde storm-petrel *Hydrobates jabejabe*, and Boyd's shearwater *Puffinus boydi*. In addition, it hosts large breeding colonies of red-billed tropicbirds *Phaethon aethurus*, brown boobies *Sula leucogaster* and white-faced storm-petrels *Pelagodroma marina*. While all Cabo Verde seabird species may be caught as bycatch, the Near Threatened and endemic Cape Verde shearwater (IUCN Red List, 2018) is likely to be particularly at risk since it almost exclusively feeds in productive commercial fishing areas off the West African coast during incubation (Hofstede and Dickey-Collas 2006; Rodrigues, 2014). This area is accountable for a high proportion of global cetacean bycatch, probably with high proportion to these megafaunal groups as well. As a result, reducing fisheries bycatch may have important benefits for the conservation of this species (Weimerskirch *et al.*, 1997, Inchausti & Weimerskirch, 2001, Lewison & Crowder, 2003, Wanless *et al.*, 2009).

Finally, Cabo Verde waters are home to at least 100 shark and ray species. Smooth-hound sharks *Mustelus mustelus*, tiger sharks *Galeocerdo cuvieri* and blue sharks *Prionace glauca* are the sharks most often captured in Cabo Verde (MAHOT, 2014; Lopes *et al.*, 2016). The practice of finning (removing fins and discarding sharks back into the water) has been prohibited since 2014 (National Resolution N°8 56/2014, July 31, BO N°8 18-Serie I). According to the Cabo Verde government, this legislation has been put in place to reduce illegal fishing practices. In addition, some EU countries have been supporting the archipelago to patrol the EEZ. Furthermore, several shark's species that occur in Cabo Verde waters have been listed on the Convention on the International Trade in Endangered Species of Flora and Fauna (CITES) which controls their trade through a permitting process and which has triggered national protections for some. This includes at least five Critically Endangered species: oceanic whitetip shark *Carcharhinus longimanus*, great hammerhead *Sphyrna mokarran*, scalloped hammerhead *Sphyrna lewini*, Blackchin guitarfish *Glaucostegus cemiculus*, and wedgefishes *Rhynchobatus* spp., two Endangered species: basking shark *Cetorhinus maximus* and whale shark *Rhincodon typus*, and four Vulnerable species: white shark *Carcharodon carcharias*, smooth hammerhead *Sphyrna zygaena*, porbeagle shark *Lamna nasus* and bigeye thresher shark *Alopias superciliosus* (MAHOT, 2014; IUCN, 2019; Rigby *et al.*, 2019).

Sampling

This study was focused on fisheries operating from five islands: Santiago, São Vicente, Santiago, Boavista, Fogo and Brava (Fig. 1), from 6 September to 31 October 2019. I conducted 94 bycatch surveys of artisanal, semi-industrial and industrial fishers. Many fishers had experience on multiple vessel types, and I completed a separate response form for each fishery, so the total number of responses for all fisheries was 160 (Table 3). For the semi-industrial and industrial fishers, I focused mainly on the two largest ports of Cabo Verde:

Mindelo (São Vicente) and Praia (Santiago) because most industrial catches are landed at these ports. For artisanal boats, surveys were conducted at beaches and ports where the artisanal boats land, on the islands with the most sea turtle nesting beaches and seabird colonies.

Table 3. Summary of surveys with the three types of fisheries at five Cabo Verde islands (n = number of fishers interviewed by each island; sample size exceeds the number of fishers because some fishers reported on multiple fisheries).

	Artisanal	Semi-industrial	Industrial	Total
Sao Vicente (n = 27)	26	13	16	55
Santiago (n = 16)	12	16	7	35
Brava (n = 13)	13	10	3	26
Fogo (n = 16)	16	3	1	20
Boavista (n = 22)	22	2	0	24
Total	89	44	27	160

Interviews were conducted with as many fishers as possible, with the assistance of presidents of fisher associations and institutions, and friends working in fisheries to identify suitable candidates. In accordance with the University of Cape Town human ethics permit, the interviews were done one-on-one to avoid interference and influence from other respondents. The average time required to complete an interview was 20 minutes, but some took over 1 hour when fishers felt comfortable to provide additional information and share stories and their experiences of working in different fisheries.

Before starting each interview, fishers were informed that this was an independent scientific investigation, not affiliated to the Cabo Verde government or fisheries management bodies. I explained that the main objective of the study was to learn how turtles, seabirds and sharks interact with fisheries and to assess the impacts caused by the three different types of vessels operating in the Cabo Verde waters. Interviews were conducted in Crioulo using a

questionnaire of 52 semi-structured questions in both open-ended and closed formats (Appendix I), adapted from Jabado *et al.* (2015) and a questionnaire used to collect seabird bycatch data in the Cabo Verde Islands from 2018 to the present (T. Militão, unpublished data).

The questionnaire was divided into four sections: 1) general information, including each fisher's background, source of income, which months they fish and how many days they spend at sea per month; 2) boat and gear characteristics, with questions about the type of boat used, their fishing schedule, the average trip duration, the main target species, the timing of setting and removing fishing gear, and their fishing areas; 3) seabird, sea turtle and shark catches, with questions on whether the fisher accidentally or intentionally catch these species and, if they do, their average monthly and annually catches, the areas, time of day, fishing gear and bait when most bycatches occur, and what they do with these species when they are caught; and 4) if they perceive any threat to the persistence of the three study groups as well as if they would like to be consulted or involved with government and NGO conservation initiatives.

Field guides to local seabirds, turtles and sharks were used to clarify species identifications (Appendix II), because fishers often only know the species by their local names which differ between islands or even communities (Compagno *et al.*, 2005). A map of the marine region in which the fishers operated was used to identify key fishing areas and the areas with the highest bycatch (Appendix III).

Statistical analysis

To determine whether the number of sea turtle, seabird and shark bycatch per year is related to the type of fishing gear (longline, handline, purse seine or gillnet), the fishing area (outside the Cabo Verde EEZ, Brava, Fogo Island and Rombo Islet, Cabo Verde EZZ, Northwest of Santo Antão, Boavista Island, Sal Island, Santiago and Maio Island and finally the area around Sao Vicente, Santa Luzia and Sao Nicolau Islands and Branco and Raso Islets) and the distance

fished from the coast, I started with Zero Inflated Negative Binomial models with an offset for the number of reported fishing days. Both distance from the coast and reported fishing days were scaled and centred to help with model convergence. For each bycatch group, I conducted backwards stepwise selection to find the best fit model based on Akaike information criterion (AIC), eventually removing the zero inflation when necessary. For seabirds, there was no bycatch by gillnets, in the area outside the Cabo Verde ZEE nor in the area around Sal Island which caused singularity in the models. Therefore, these categories were removed from the analysis of this group. The models were run in R using the package pscl (Jackman 2020).

To estimate the total amount of turtle, seabird and shark bycatch per year in different fisheries, I first estimated the total number of vessels using each gear type in Cabo Verde. For industrial fisheries, I used the number of permits recorded by IMar for longlines, tuna pole fishing and tuna purse seine from 2018. For artisanal and semi-industrial fisheries, IMar only had information on the total number of vessels active in 2018. Therefore, I extrapolated the proportion of different fishing gears recorded in 2012 (handline, purse seine, scuba, gillnet and beach net) onto the total number of vessels in 2018, resulting in an estimate of the number of artisanal and semi-industrial vessels using each gear-type in 2018. Then, I estimated the annual bycatch per by gear type using the following steps:

- 1) Subset data to gears used by at least 10 respondents (handline, purse seine, scuba, gillnet, longline)
- 2) Converted the 4 categories quantifying bycatch (0, 1-4, 5-9, >9) into two numerical estimates: the minimum bycatch estimates as the minimum value for each category (0, 1, 5 and 10)
- 3) Calculated the annual bycatch of each turtle, seabird and shark species per respondent by multiplying the two numerical estimates (minimum and best bycatch estimates) for

each species by the number of months a year in which the fisher reported catching these species

- 4) Calculated the total annual turtle, seabird and sharks per respondent by summing the annual catch of all species within each megafauna group for both the minimum and best bycatch estimates.
- 5) Calculated the mean and standard deviation of the total annual turtle, seabird and shark bycatch per gear type for both the minimum bycatch estimates.
- 6) Multiplied the minimum bycatch estimates means and standard deviations for each gear type by the total estimated number of fishing vessels using the same gear.

Results

Description of Cabo Verde fisheries

Fisheries in Cabo Verde waters use eight main fishing gears and three vessel types (artisanal, semi-industrial and industrial) to catch a wide variety of species. The interviews confirmed that artisanal, semi-industrial and industrial vessels used different combinations of fishing gears, crew numbers, boat size, and engine capacity. In artisanal vessels, handlines were the most used as a main fishing gear (89% of 73 respondents). The crews were composed of groups of 2 to 10 fishers and the boats were 3-9 m long with 5 to 25 hp outboard engines. Semi-industrial vessels mainly used purse seine nets (82% of 38 respondents). Crews consisted of 4 to 25 fishers and the boats were 8 to 22 m long with ~2500 hp inboard engines. Lastly, all industrial fishers reported used longline and pole fishing as a main fishing gear, (n = 22 and 4) respectively, with a crew of 9 to 24 individuals. Vessels were between 27 to 47 m long with unknown engine power. The artisanal and semi-industrial vessels fished largely over the shallow shelf waters surrounding Cabo Verde's islands and islets (Figs 3 and 4), while industrial vessels fished throughout most of the country's EEZ (Fig. 5). Fishers from artisanal

and semi-industrial vessels reported fishing up to depths of 200 ± 66.6 m mainly with handline, while industrial vessels fished at 20 ± 9.3 m deep, targeting pelagic fish (Table 4).

Table 4. Summary of percentage of fishers using the main different fishing gear by vessel type (numbers in parentheses = sample size)

Vessel type	Gear	Active boats used as main fishing gear in 2018	% of respondents used as main fishing gear, n=160
Artisanal	Handline	1452 ^a	89 (65)
	Purse seine	53 ^a	16 (6)
	Gilnet	40 ^a	74 (14)
	Scuba dive	15 ^a	100 (4)
Semi-industrial	Handline	32 ^a	11 (8)
	Purse seine	64 ^a	82 (31)
	Gilnet	20 ^a	26 (5)
	Scuba dive	1 ^a	0
	Pole fishing	3 ^a	0
Industrial	Longline	27 ^a	100 (22)
	Purse seine	4 ^a	3 (1)
	Pole fishing	5 ^a	100 (4)

^a Data on numbers of operating boats in Cabo Verde in 2018 From Instituto Nacional de Desenvolvimento das Pescas (INDP)

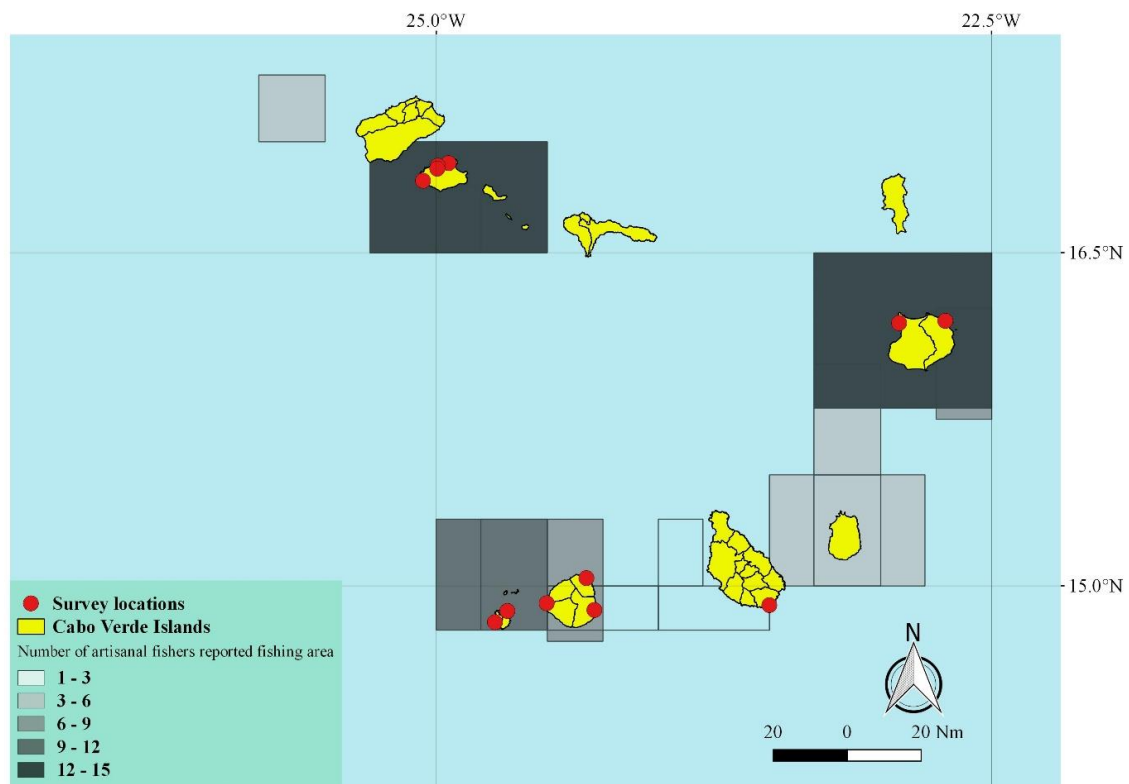


Fig. 3 Main artisanal fishing areas around the Cabo Verde archipelago (red dots show where interviews took place)

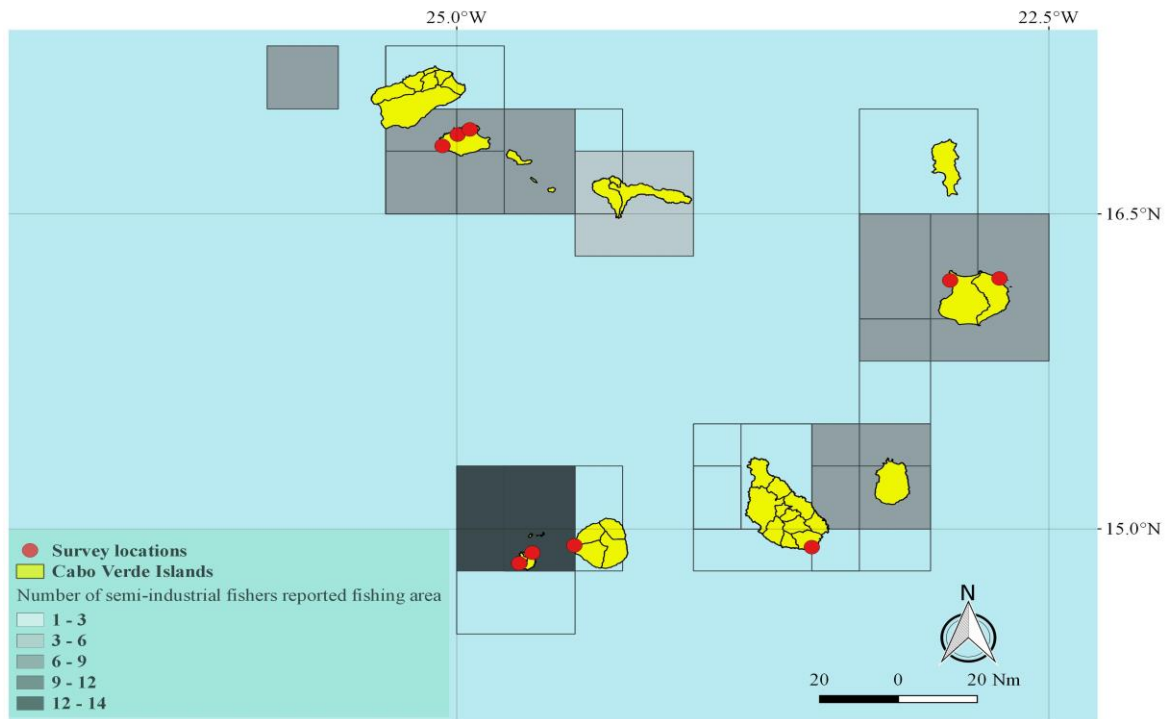


Fig. 4 Main semi-industrial fishing areas around the Cabo Verde archipelago (red dots show where interviews took place)

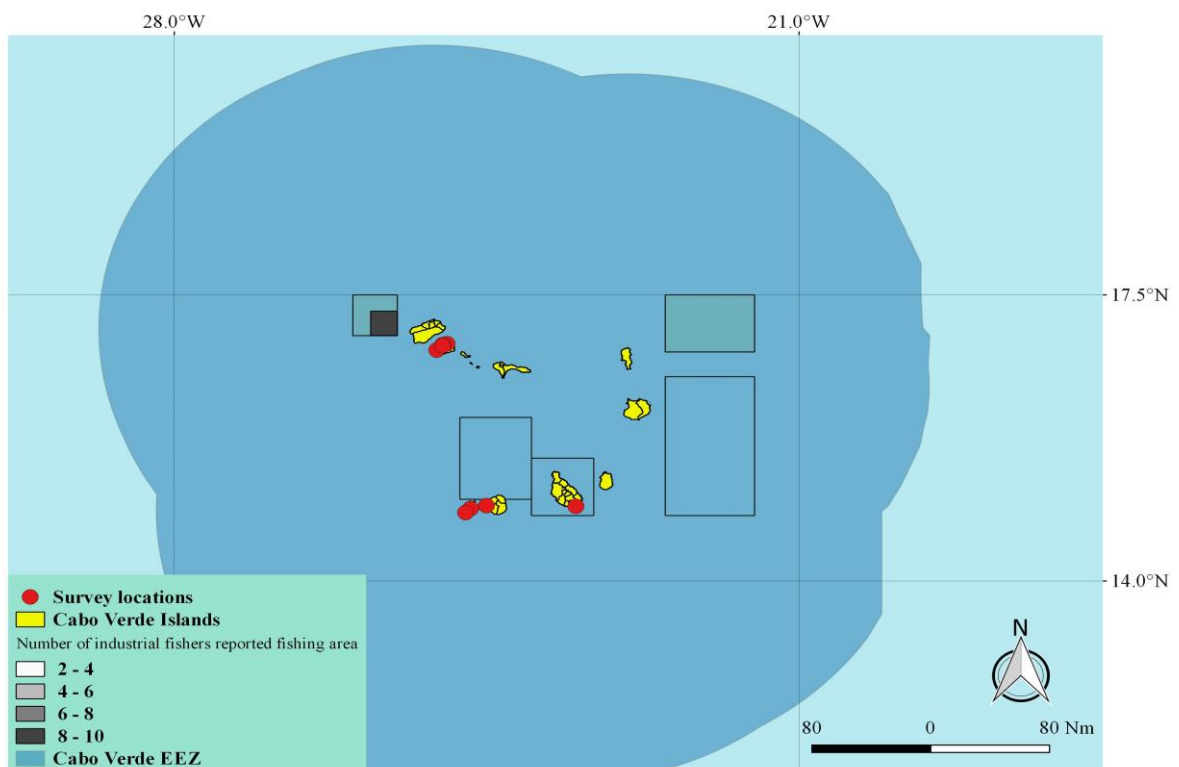


Fig. 5 Main industrial fishing areas around the Cabo Verde archipelago (red dots show where interviews took place). Since all 22 industrial fishers reported fishing throughout the EEZ, only the areas that fishers defined as important fishing areas are displayed.

Among all target species in Cabo Verde fisheries, yellowfin tuna *Thunnus albacares*, grouper *Serranidae* sp., wahoo *Acanthocybium solandri*, scad *Decapterus* sp. and bigeye scad *Selar crumenophthalmus* were the most caught in all five islands where interviews were conducted. Industrial vessels had the largest catches and were most target-specific, mainly focused on yellowfin tuna, sharks and swordfish *Xiphias gladius*, while artisanal and semi industrial fisheries targeted a much wider diversity of species (Table 5).

Table 5. Percentage of fishers reported to fish the main target species by the main different fishing gear used in Cabo Verde archipelago, sample sizes of each fishing gear in brackets.

Target species	Handline (73)	Longline (22)	Purse seine (38)	Gillnet (19)	Scuba dive (4)	Pole fishing (4)
yellowfin tuna (<i>Thunnus albacares</i>)	85	77	-	-	-	100
wahoo (<i>Acanthocybium solandri</i>)	72	5	2	-	-	13
groupers (Serranidae spp.)	71	-	-	-	66	-
Atlantic emperor (<i>Lethrinus atlanticus</i>)	32	-	-	-	8	-
lesser amberjack (<i>Seriola fasciata</i>)	29	-	2	4	8	-
common dolphinfish (<i>Coryphaena hippurus</i>)	28	-	-	4	-	-
bigeye scad (<i>Selar crumenophthalmus</i>)	27	-	74	67	-	-
guinean grunt (<i>Parapristipoma humile</i>)	16	-	-	-	-	-
skipjack tuna (<i>Katsuwonus pelamis</i>)	15	-	-	-	-	88
golden African snapper (<i>Lutjanus fulgens</i>)	14	-	16	-	-	-
frigate tuna (<i>Auxis thazard</i>)	12	-	47	8	-	13
scad (Decapterus sp.)	12	-	74	29	-	-
blue runner (<i>Caranx crysos</i>)	9	-	2	8	8	-
goat fish (<i>Pseudupeneus prayensis</i>)	7	-	-	4	-	-
seabreams (Sparidae spp.)	6	-	-	-	-	-
black jack (<i>Caranx lugubris</i>)	5	-	2	13	-	-
blackspot picarel (<i>Spicara melanurus</i>)	5	-	9	67	-	-
blue marlin (<i>Makaira nigricans</i>)	10	37	-	-	-	-
smooth flounder (<i>Citharichthys stampflii</i>)	5	0	-	-	-	-
swordfish (<i>Xiphias gladius</i>)	2	82	-	-	-	-
slack seabream (<i>Spondylisoma cantharus</i>)	1	-	-	8	-	-
parrot fish (Scaridae Sp)	8	-	-	13	50	-
Crustacean / mollusc spp	-	-	-	-	74	-
morays (Muraenidae spp)	16	-	-	-	17	-
monrovia Surgeonfish (<i>Acanthurus monroviae</i>)	-	-	-	4	8	-
pompano (<i>Trachinotus ovatus</i>)	-	-	5	17	-	-
Sharks spp	-	91	-	13	-	-
West African goatfish (<i>Pseudupeneus prayensis</i>)	-	-	-	8	-	-
lesser African threadfin (<i>Galeoides decadactylus</i>)	-	-	2	4	-	-
little tunny (<i>Euthynnus alleteratus</i>)	-	0	7	-	-	-

Factors affecting bycatch

Overall, 78% of fishers reported accidental catch of turtles, 66% reported seabird and 91% reported shark bycatch. Turtle bycatch was most often reported by fishers using industrial

longlines (86%), followed by artisanal handline (55%), and by semi-industrial vessel purse seine (50%). The proportion of fishers that reported seabird bycatch was greatest among artisanal fishers using handlines (77%) and longlines (32%). All fishers from industrial vessels using longlines reported shark bycatch, followed by handlines, purse seines and gillnets, all with over 50% of positive responses (Table 6).

Table 6. Summary of the % fishers reporting turtle, seabird and shark bycatch on different fishing gear and vessel types in Cabo Verde waters (n = number of respondents used main fishing gear by each fishery)

	Turtles			Seabirds			Sharks		
	Artisanal	Semi-industrial	Industrial	Artisanal	Semi-industrial	Industrial	Artisanal	Semi-industrial	Industrial
Handline (n = 73)	55	4	0	77	8	0	86	7	0
Purse seine (n = 38)	5	50	3	3	0	0	11	53	3
Longline (n = 22)	0	0	86	0	0	32	0	0	100
Pole and line fishing (n = 4)	0	0	0	0	0	50	0	0	25
Gillnet (n = 19)	47	11	0	-	-	-	58	11	0

Artisanal, semi-industrial and industrial fishers reported that bycaught turtles were preferably released alive, as they know their capture is banned by law. Some fishers reported to have tried to remove the hooks before releasing turtles. However, 27% of fishers reported either discarding turtle's dead, using them as bait or selling them. Only 8% artisanal fishers reported that some turtles were sold mainly in their village. One fisher working on an industrial longline vessel commented that the fate depended on the species: large leatherback turtles that are too big to lift onto the boat are released alive whereas smaller species are hauled aboard and killed to retrieve the hook and then discard at sea (additionally one fisher reported that leatherback turtle meat tastes bad). Regarding seabird bycatch, all fishers reported to have tried to remove the hooks or even cut the line to released seabirds alive when possible. However, when seabirds were caught dead, 21% of fishers reported to release the carcass and only 3% kept the carcass to eat. Finally, fishers reported 83% and 71% of sharks bycatch were preferably kept to be eaten and sold respectively, and only 53% reported releasing some sharks alive. This suggests that shark bycatch mortality is much higher than the other megafauna groups.

Most fishers reported that sea turtle bycatch did not differ between bait types used (58%; Table 7). However, 16% of fishers suggested bycatch was higher in sea turtles when using scad as bait. All fishers that reported seabird bycatch suggested that it occurred mainly when using bigeye scad (40%) as bait, followed by scad (24%). Finally, fishers reported that sharks are mainly bycaught when they used baits as the frigate tuna (28%) and scad (24%), although 18% also reported they could be caught with any bait (Table 7).

Table 7. Fishery-specific usage of bait most likely to catch turtles, seabirds and sharks in Cabo Verde waters

Specific bait use	Turtles	Seabirds	Sharks
Any bait type	58	12	18
Scad (<i>Decapterus</i> spp.)	16	24	24
Bigeye scad (<i>Selar crumenophthalmus</i>)	9	40	7
Frigate tuna (<i>Auxis thazard</i>)	2	8	28
Octopus (<i>Octopus</i> spp.)	9	1	5
Skipjack tuna (<i>Katsuwonus pelamis</i>)	0	0	8
Blackspot picarel (<i>Spicara melanurus</i>)	0	9	0
Madeiran sardinella (<i>Sardinella maderensis</i>)	1	3	1
Yellowfin tuna (<i>Thunnus albacares</i>)	0	0	3
Common dolphinfish (<i>Coryphaena hippurus</i>)	2	1	1
Blue runner (<i>Caranx crysos</i>)	0	0	2
Almoco jack (<i>Seriola rivoliana</i>)	0	0	1
Black seabream (<i>Spondyliosoma cantharus</i>)	0	0	1
Lubbock's chromis (<i>Chromis lubbocki</i>)	0	1	0
Crabs (Decapoda)	1	0	0
Tropical two-wing flyingfish (<i>Exocoetus volitans</i>)	1	0	0

The location of highest bycatch overlapped largely with the fishing areas reported by fishers. The artisanal fishery had the highest bycatch of turtles around the Rombo Islets, Brava and Boa Vista Islands (Fig. 6.a), seabirds around the Rombo, Raso and Branco Islets, Brava, Boavista and Santa Luzia Islands and west of Sao Vicente Island (Fig. 6.b), whereas sharks were caught around Sao Vicente and Santa Luzia Islands, Raso and Branco Islets and west of Santo Antão (Fig. 6.c). For the semi-industrial vessels, Boavista Island appears to be the most important area for turtle bycatch, followed by around of Rombo, Branco and Raso Islets and around of Sao Vicente and west of Santo Antão Islands (Fig. 7.a). For seabirds, the important areas are

around Branco and Raso Islets and Santa Luzia Island (Fig. 7.b), whereas sharks show the highest bycatch around Branco and Raso Islets, Rombo Islets and around of Brava Island (Fig. 7.c). Finally, most fishers from industrial vessels, which operate mainly in oceanic waters, reported equal bycatch throughout the EEZ (55%, 32% and 91%) for turtles, seabirds and sharks respectively (Fig. 8). According to them, the area along the 13-18 Nautical miles legal fishing limit around the Islands and Islets is where the majority of bycatch occurs. Other important bycatch areas are Northwest of Santo Antão, West of Boa Vista and North of Fogo and Brava (Fig. 8.a, b and c).

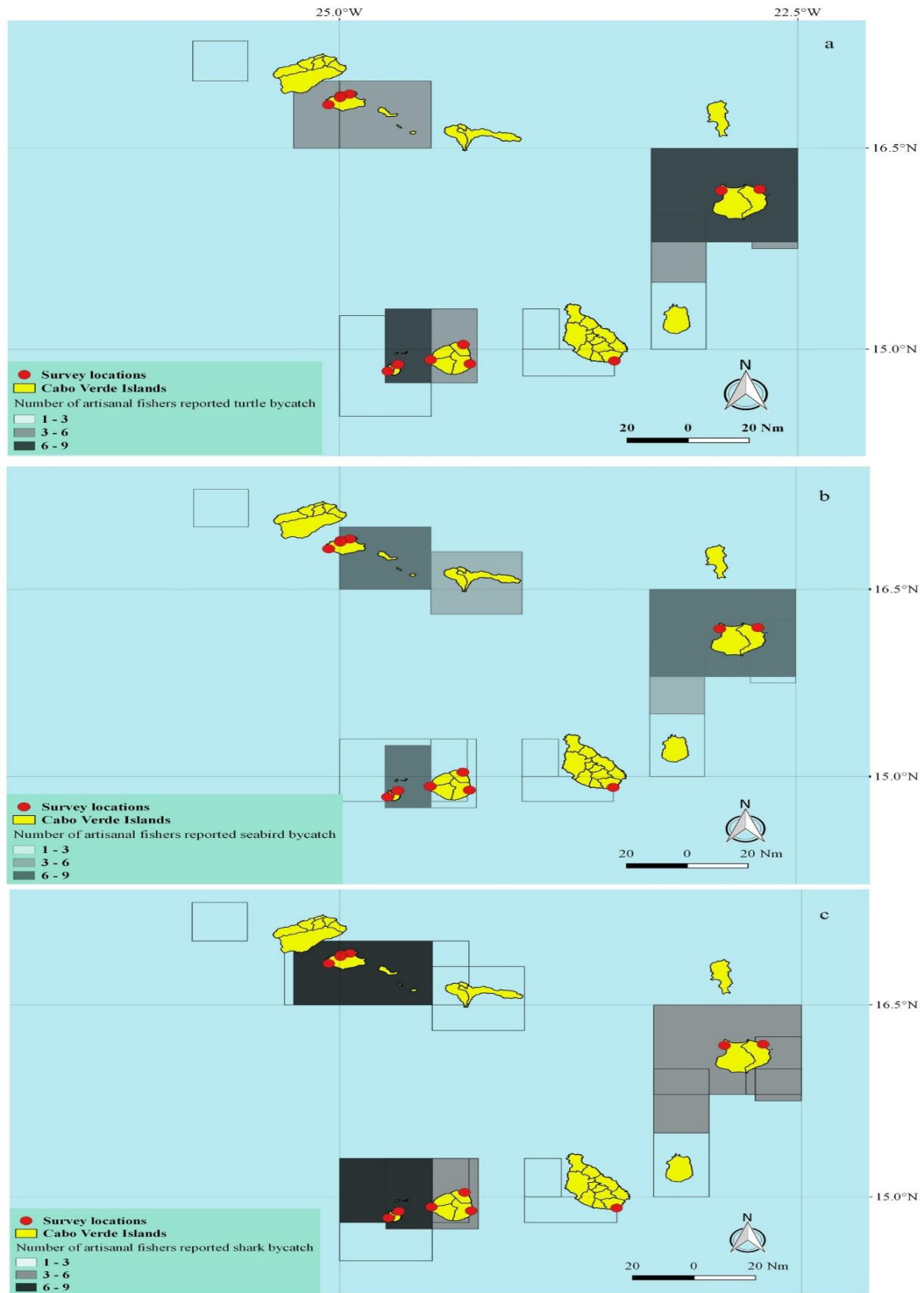


Fig. 6 Summary of distribution catch areas from artisanal vessels by marine megafauna group (a: turtles, b: seabirds and c: sharks)

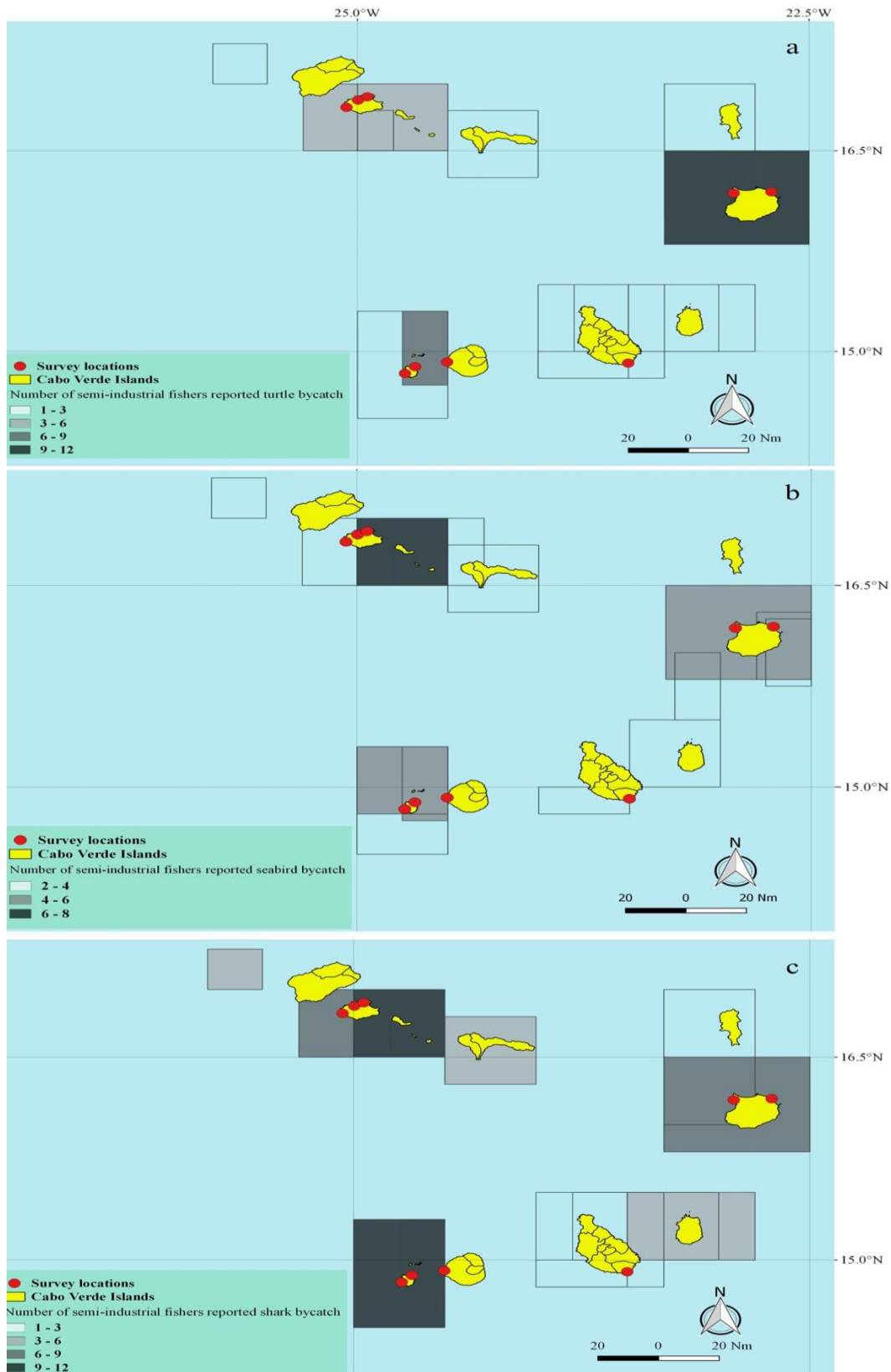


Fig. 7 Summary of distribution catch areas from semi-industrial vessels by marine megafauna group (a: turtles, b: seabirds and c: sharks)

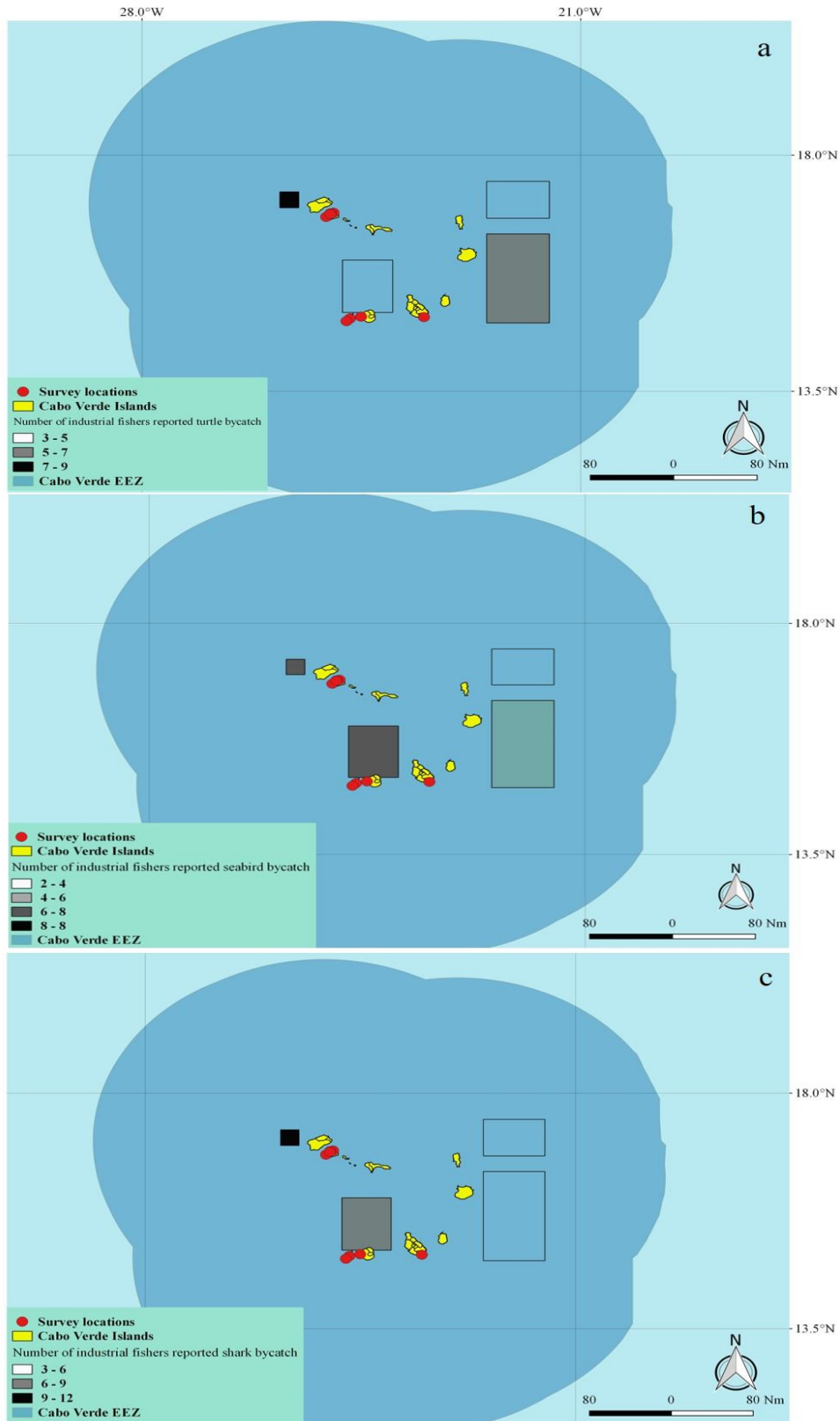


Fig. 8 Summary of distribution catch areas from industrial vessels by marine megafauna group (a: turtles, b: seabirds and c: sharks). Since all industrial fishers that reported turtle (17), seabird (9) and sharks (22) bycatch reported catching these species throughout the EEZ, only the areas that fishers defined as important bycatch areas are displayed.

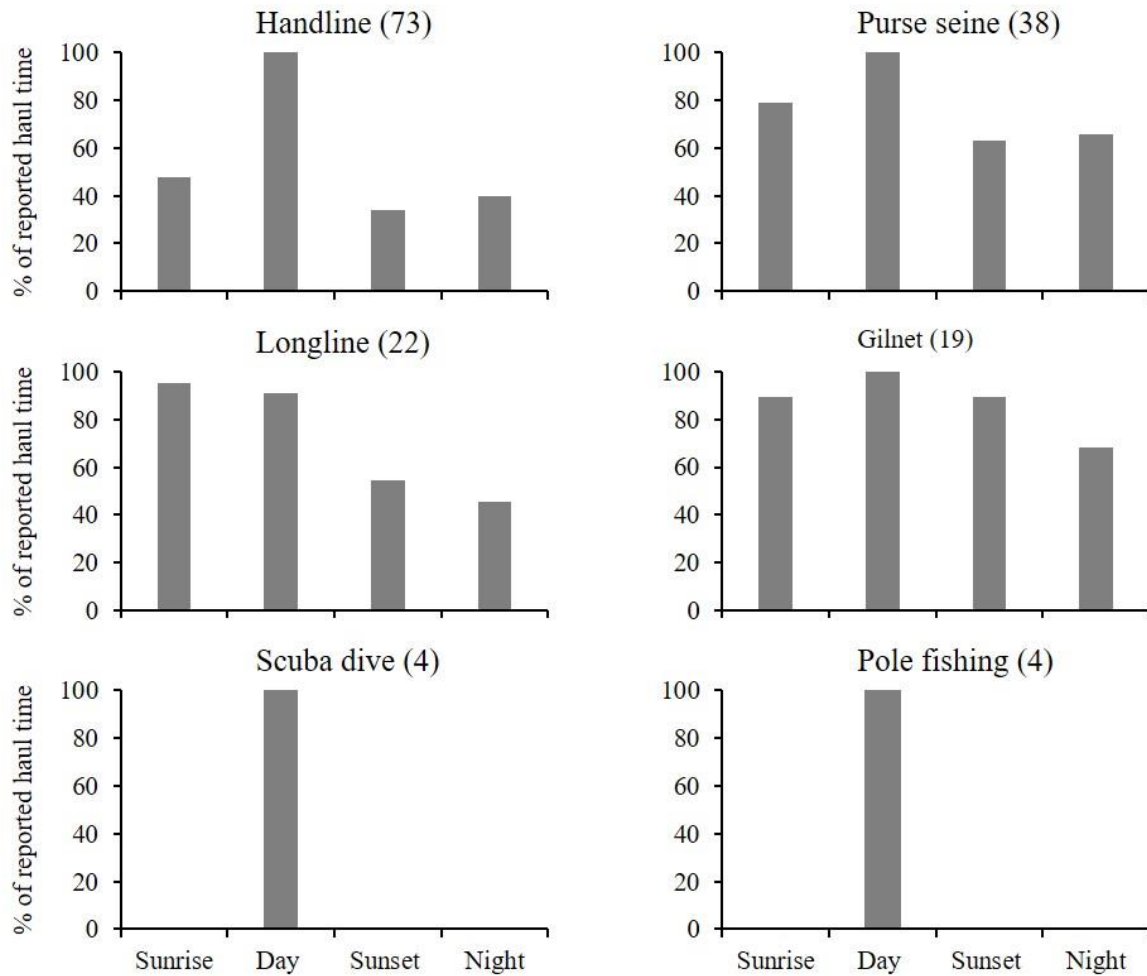


Fig. 9 Fishers reported the main time to remove the fishing gear during the fisheries activity in all vessels type, number inside the parentheses mean the sample size per each main fishing gear.

Fishers reported the day as a main time to remove fishing gear range from 91 % - 100% of reports in all gear types, suggesting that fishing generally occurs during daylight (Fig. 9). Resultingly, turtle, seabirds and shark bycatch also mainly occurred during the day, largely between 6h – 12h with 78%, 62% and 86%, respectively (Fig. 10).

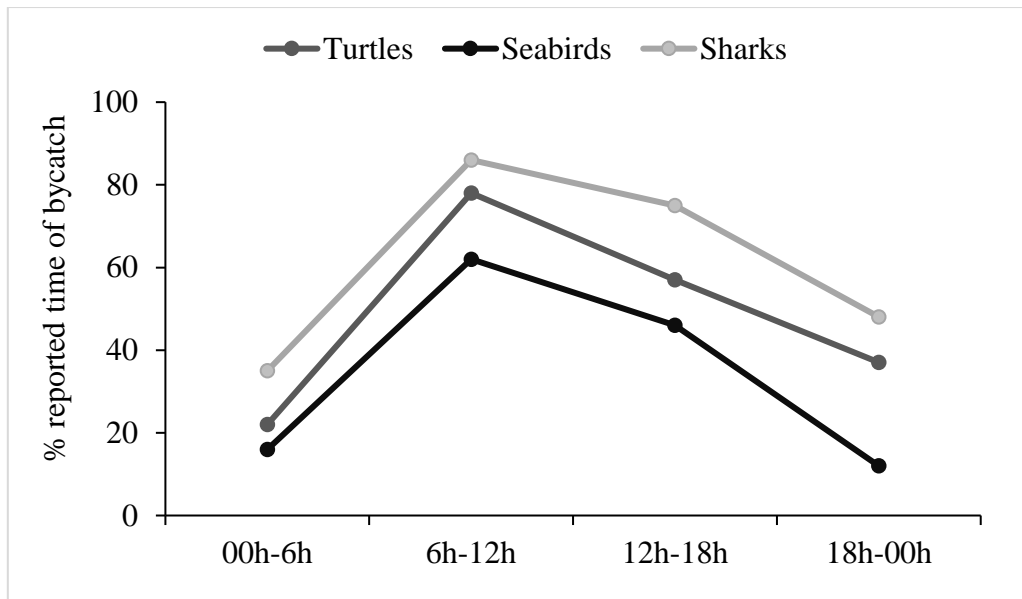


Fig. 10 The relative percentage of fishers reporting turtle, seabird and shark bycatch at different times of day

Among turtles, loggerheads bycatch is the highest and varies the most throughout the year, occurring mainly between May to October, which coincide mainly with their nesting season (June to October). Green turtle bycatch varied slightly throughout the year with a peak between May and October as well. All other turtle species are reportedly caught at the same rate throughout the year (Fig 12). Among seabirds, Cape Verde shearwaters have the highest levels of bycatch and varied the most throughout the year, occurring mainly during May to October (Fig. 13), which coincide mostly with their breeding period and fishing months (Fig. 11). All other seabird species are caught less frequently, and their bycatch vary little during the year (Fig 13). Finally, sharks are bycaught in nearly the same proportion throughout the year (Fig 14).

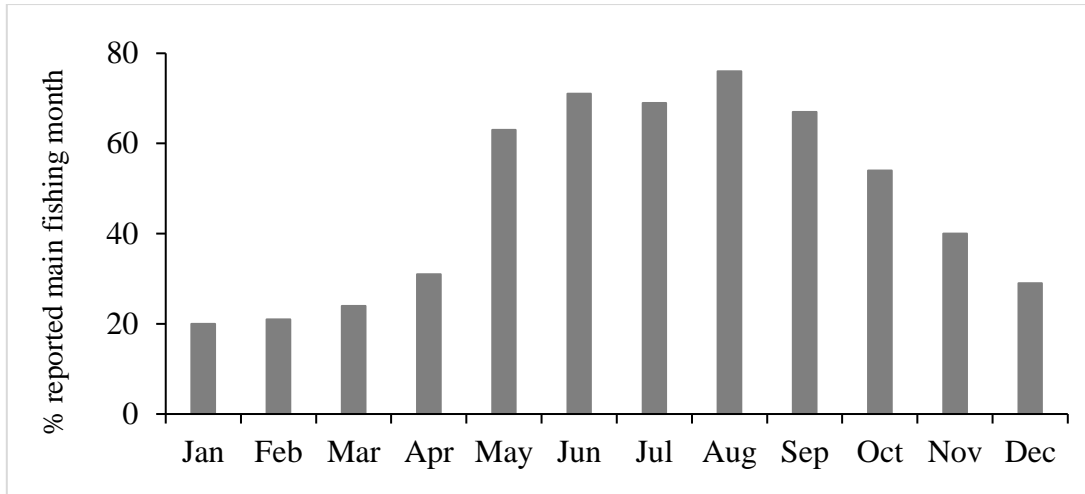


Fig. 11 Percentage of fishers reported the main month to fish in Cabo Verde water

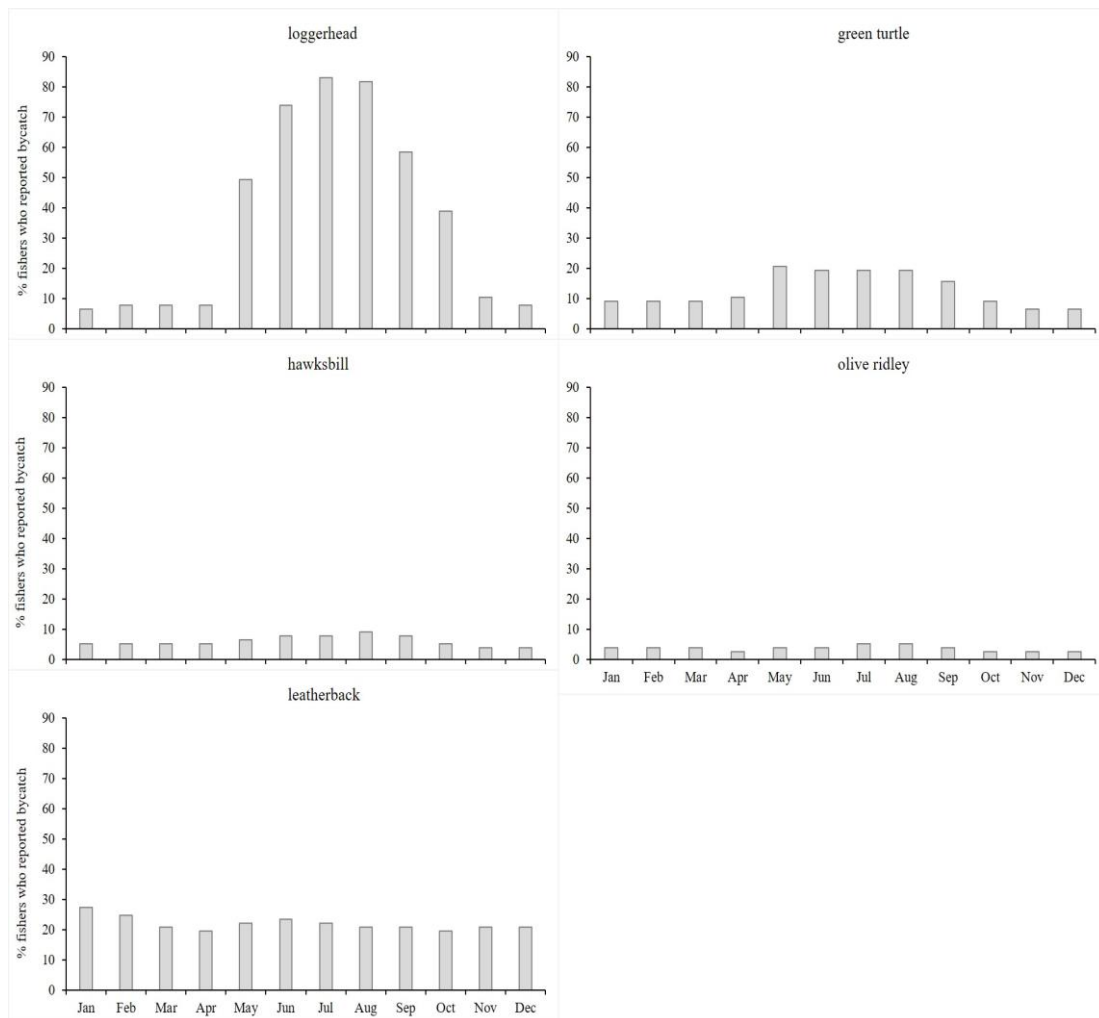


Fig. 12 Variation of turtle’s bycatch throughout the year. Bars show the percentage of fishers reporting catching each species per month, across all fisheries

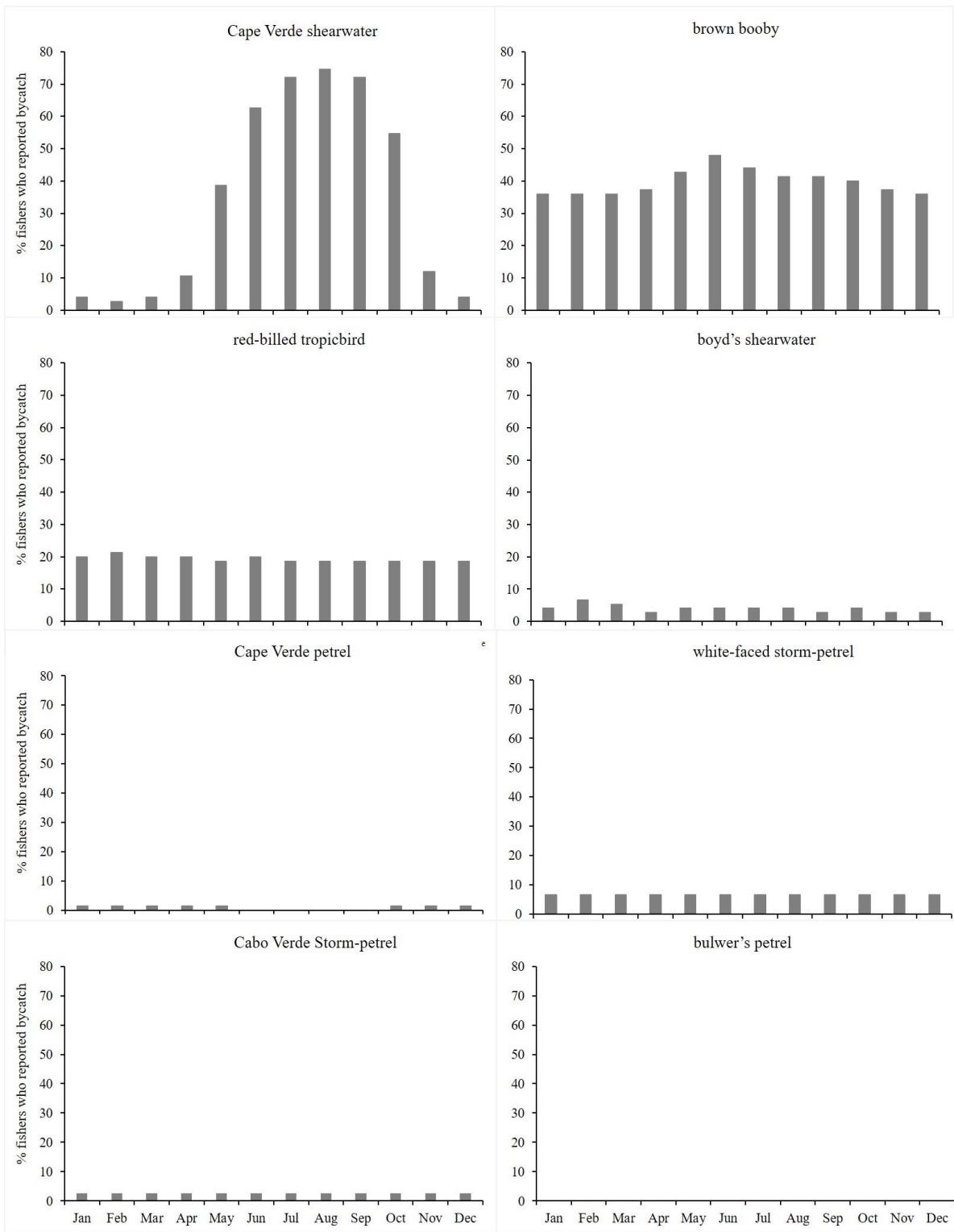


Fig. 13 Variation of seabird bycatch throughout the year. Bars show the percentage catch variation along the year, and each graphic show the different seabird's species

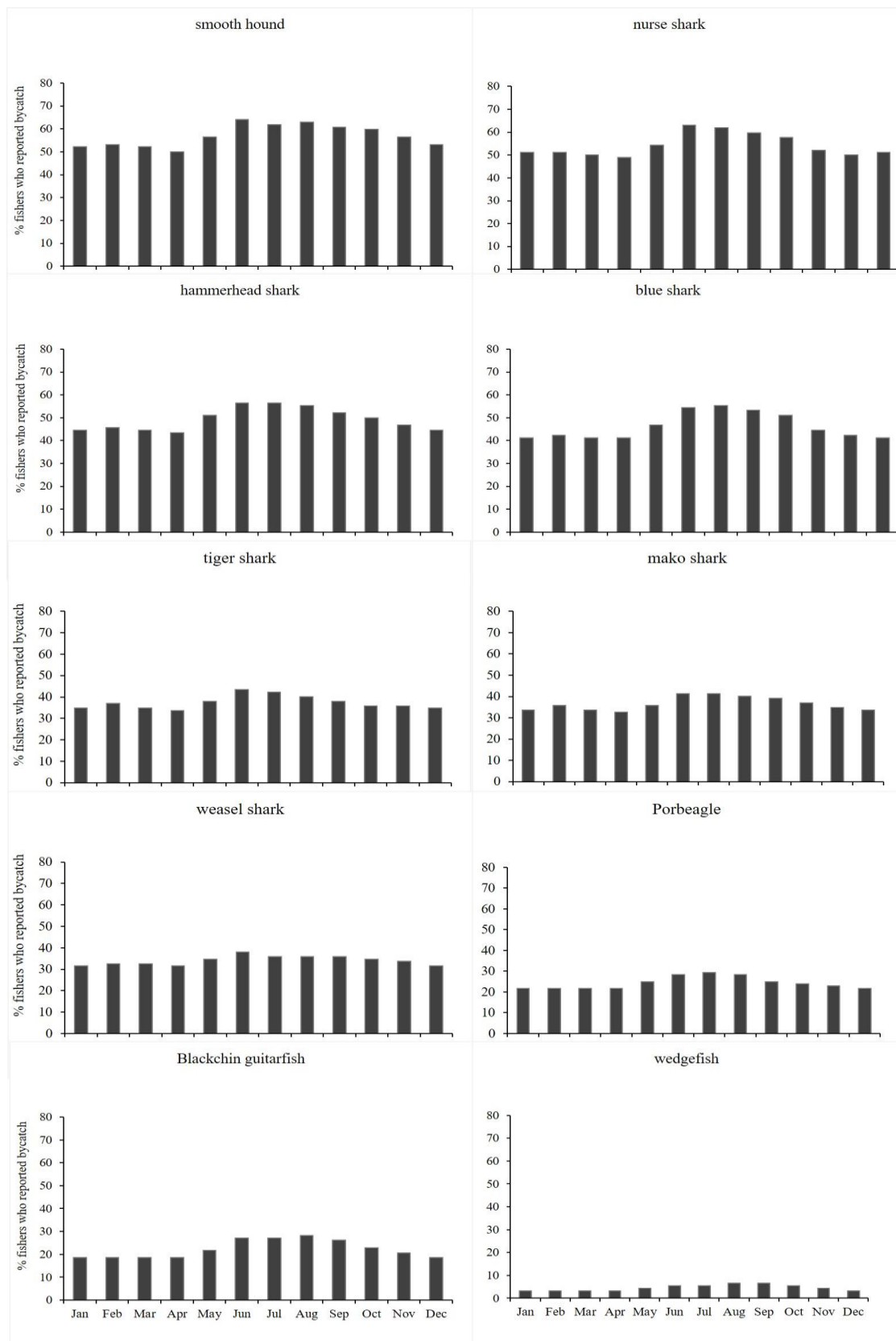


Fig. 14 Variation of shark's bycatch throughout the year. Bars show the percentage catch variation along the year, and bars colour show the different shark species.

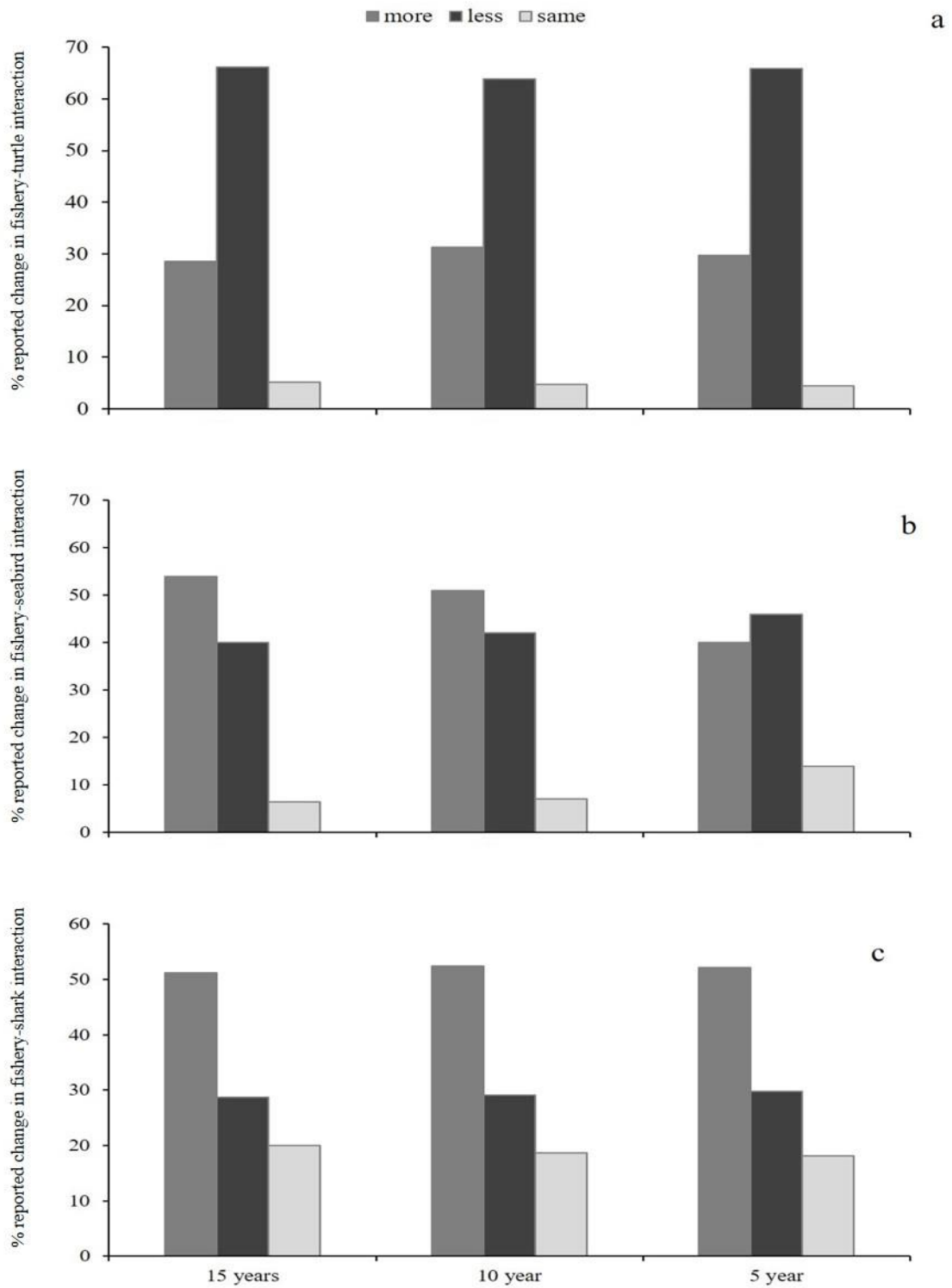


Fig. 15 Percentage of fishers who reported that there were more, less, or the same number of interactions with (a: turtles, b: seabirds and c: sharks in 15, 10 and 5 years ago

Fishers reported the increase of turtle interactions with fisheries in the last 15 years (Fig. 15.a), and with seabirds in the last 5 years (Fig. 15.b). For sharks, they reported a decrease of interactions with fisheries in the last 15 years (Fig. 15.c). They were also concerned with the

future conservation of these megafauna group. In 84% and 95% of interviews, fishers reported that they were concerned for the future of turtle and seabird conservation. In sharks, this number was less high, with 67% of respondents expressing concern for shark protection.

Bycatch in the various fishery sectors

Turtle bycatch

All five sea turtle species that occur in Cabo Verde's EEZ were reported to be bycaught in handline, purse seine, gillnet and longline. Loggerhead turtles were reported to be the most common species caught from artisanal, semi-industrial and industrial vessels. The fishing gear most often linked to loggerhead bycatch were handlines on artisanal (100%, n = 40), purse seine on semi-industrial (95%, n = 19) and longline on industrial vessel (63%, n=19). Leatherbacks were caught largely by industrial, mainly in longline fishing gear 89%, n = 19) (Fig. 16).

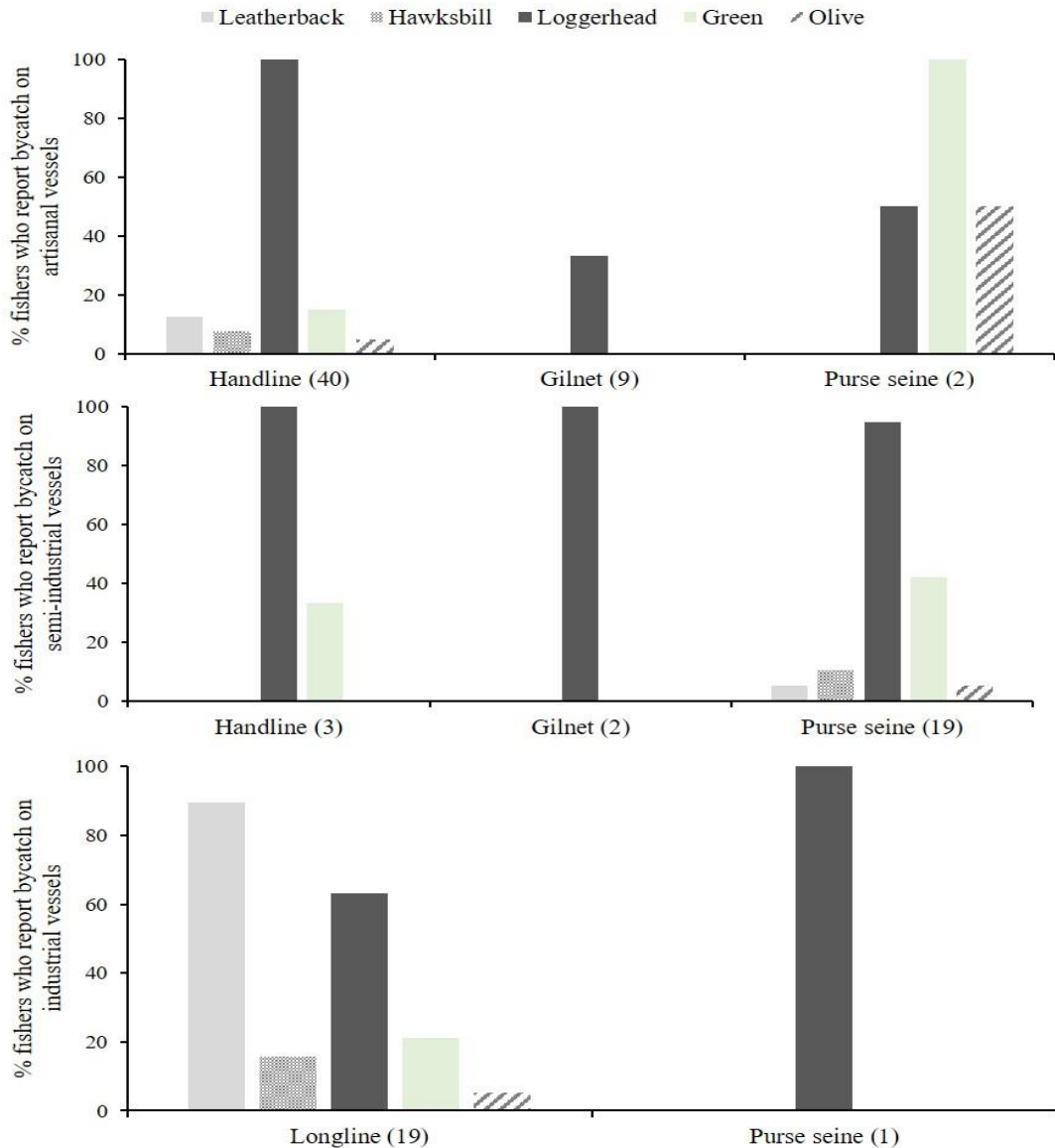


Fig. 16 Summary of turtle's bycatch by different fishing gear operating in Cabo Verde waters, number in brackets mean the number of bycatches by each fishing gear on different vessels type.

Factors related to the amount of yearly turtle bycatch

The best supported model for yearly turtle bycatch was a negative binomial model with the coefficient fishing gear (Table 8). In comparison to longlines, handlines and purse seines caught significantly less bycatch, while the difference with gillnets was insignificant (Table 9).

Table 8. Model comparison for the turtle’s bycatch. The best-fitting model is indicated in bold font. All models listed also included random effects for interview ID. The low Akaike Information Criterion (AIC) of the top model mean the best model

Model	Parameters	df	LogLik	AIC	w
ZINB_turtle_3	main Fishing gear + offset (fishing days per year)	5	-550.110	1110.6	0.882
ZINB_turtle_2	main fishing gear + offset (fishing days per year) main fishing gear	9	-547.706	1114.7	0.116
ZINB_turtle_1	main fishing gear + fishing area +offset (fishing days per year) main fishing gear	16	-543.991	1124.0	0.001
ZINB_turtle	main fishing gear + fishing area + maximum distance to coast to fishing +offset (fishing days per year) main fishing gear	17	-543.549	1125.7	0.000

The most conservative sea turtle annually bycatch estimate (mean estimate and standard deviation) reported by fishers varied strongly by species and by fishing gear. Loggerhead were the species with the highest reported bycatch in handline and purse seine fishing gear, followed by green turtle and leatherback. Leatherback sea turtles were also commonly bycaught, especially by longline fishing gear (Table 10). These values were also highly variable, suggesting that although fishers used the same gear, they often declared different amounts of bycatch (Table. 10). When the mean annual number of sea turtles bycaught per fishing gear was extrapolated over the number of vessels operating in Cabo Verde, the total number of turtles bycaught by handline was higher than in other fishing gears (Table. 10).

Table 9. Summary of the results of the model investigating how the reported number of bycaught turtles per year related to whether fishers worked on different fishing gear. Estimates of fishing gear are calculated in relation to longline.

Fishing gear	Estimate	std. Error	Z value	Pr(> z)
(Intercept)	4.7071	0.4595	10.244	<2e-16***
Handline	-1.8281	0.5253	-3.480	0.000502***
Purse seine	-1.5182	0.5786	-2.624	0.008695**
Gilnet	-0.9681	0.6762	-1.432	0.152218

Table 10. Estimation of the total annual turtle bycatch per fishing gear type in Cabo Verde. Ranges indicate the mean and SD estimates

Main fishing gear	Leatherback	Hawksbill	Loggerhead	Green	Olive
Fishing pole	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
Gilnet	6 ±19	0 ±0	704 ±1084	73 ±276	0 ±0
Handline	1171 ±5536	527 ±2845	16397 ±25211	1776 ±7569	410 ±2682
Longline	1690 ±1436	36 ±98	596 ±847	448 ±1136	147 ±691
Purse seine	142 ±765	31 ±135	1081 ±1595	585 ±1566	40 ±197
Scuba dive	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0

Seabird bycatch

Cape Verde shearwaters were the most commonly reported bycaught species, followed by brown boobies and red-billed tropicbirds. All three species were mainly caught on handlines (76%, 53% and 22%, respectively, n = 55 respondents reported bycatch on artisanal vessel type). Fishers from industrial vessels reported 100% of bycatch on Cape Verde Shearwater on longline and pole fishing (n = 7 and 2 respondents reported bycatch, respectively (Fig. 17). Trawls, gillnet, beach net and scuba dive had no seabird bycatch in Cabo Verde waters.

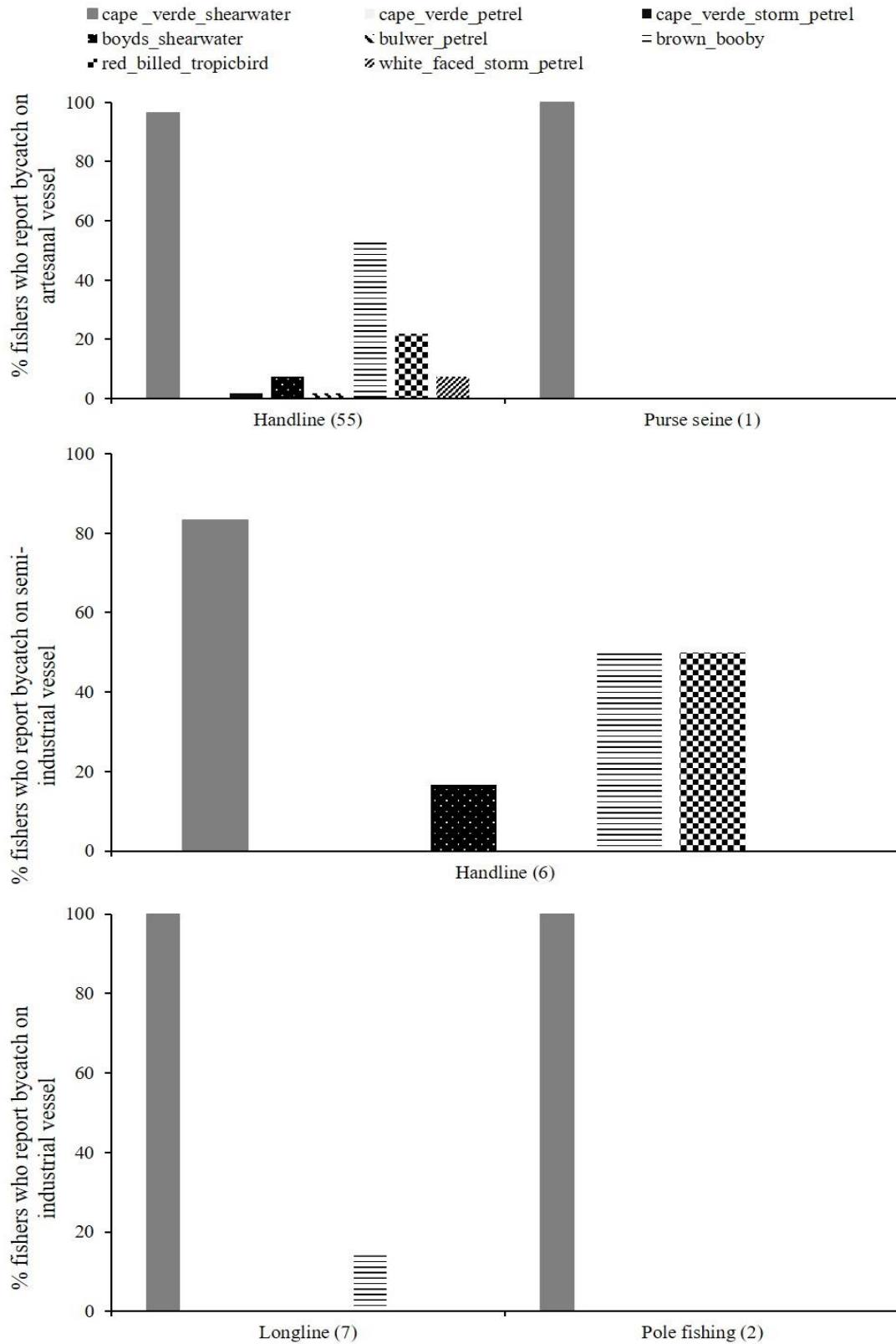


Fig 17. Summary of seabird's bycatch by different fishing gear operating in Cabo Verde waters, number in brackets mean the number of bycatches by each fishing gear on different vessels type.

Factors related to the amount of yearly seabird bycatch

The best supported model for yearly seabird bycatch was a zero inflated negative binomial model with the count model coefficients fishing gear and fishing area and zero-inflation model coefficient fishing gear (Table 11). In comparison to longlines, seabird bycatch was significantly lower in purse seines, although there was no significant difference with handline. Moreover, in comparison to the area around Fogo and Brava, seabird bycatch was significantly lower in the Northwest of Santo Antão, Boavista Island, and around Sao Vicente, Santa Luzia and Sao Nicolau Island and Branco and Raso Islets (Table. 12). However, there was no significant difference with the area within all Cabo Verde EEZ and between Maio and Santiago. Moreover, the model shows that in comparison to longline, there were significantly higher probabilities of false zeros (unreported or unobserved seabird bycatch) obtained by handline and lower probabilities in purse seine. (Table 12).

Table 11. Model comparison for the seabird’s bycatch. The best-fitting model is indicated in bold font. All models listed also included random effects for interview ID. The low Akaike Information Criterion (AIC) of the top model mean the best model

Model	Parameters	df	LogLik	AIC	w
ZINB_seabird_2	main fishing gear + fishing area + offset (fishing days per year) main fishing gear	12	-383.353	793.5	0.776
Full Model	main fishing gear + fishing area + maximum distance to coast to fishing +offset (fishing days per year) main fishing gear	13	-383.350	-3.3193	1.6155
ZINB_seabird_3	main fishing gear + offset (fishing days per year) main fishing gear	7	-399.146	813.2	0.000

The mean bycatch of seabirds per year varied strongly by species and by fishing gear. Cape Verde shearwaters, brown boobies and red-billed tropicbirds were the most commonly reported species mainly in handline fishing gear (Table 13). The reported yearly bycatch of seabirds by handline vessels was higher than in other gear types (Table 12, Table 13). The reported yearly bycatch was also highly variable, suggesting that fishers using the same gear often declared

different bycatch rates. Moreover, when the mean annual number of seabirds bycaught per fishing gear was extrapolated over the number of vessels operating in Cabo Verde, the total number of seabirds bycaught by handline remained several magnitudes higher than in other fishing gears (Table 13).

Table 12. Summary of the results of the model investigating how the reported number of bycaught seabirds per year related to whether fishers worked on different fishing gear. Estimates of fishing gear are calculated in relation to fishers from longline.

Fishing area / Fishing gear	Estimate	std. Error	Z value	Pr(> z)
Count model coefficients (negative binominal with log link)				
Intercept	5.1937	0.7989	6.501	7.98e-11 ***
Handline	0.3100	0.7447	0.416	0.6772
Cabo Verde EZZ area	-1.4374	0.9985	-1.440	0.1500
Northwest of Santo Antão	-1.5318	0.7196	-2.129	0.0333 *
Boavista Island	-2.3488	0.4247	-5.531	3.18e-08 ***
Santiago and Maio Island	-1.5357	0.8239	-1.864	0.0623 .
Sao Vicente, Santa Luzia and Sao Nicolau Island and Branco and Raso Islets	-1.9772	0.3812	-5.187	2.13e-07 ***
Zero-inflation model coefficients (binominal with logit link)				
(Intercept)	0.1759	0.5240	0.336	0.73705
Handline	-2.1335	0.6785	-3.145	0.00166**
Purse seine	2.8432	1.2535	2.268	0.02332*

Table 13. Estimation of the total annual seabirds' bycatch per fishing gear type in Cabo Verde. Ranges indicate the mean and SD estimates

Main fishing gear	Cape Verde shearwater	Cape Verde petrel	Cape Verde storm petrel	Boyd's shearwater	Bulwer petrel	Brown booby	Red billed tropicbird	White faced storm petrel
Fishing pole	33 ±47	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
Gillnet	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
Handline	30764 ±31235	0 ±0	0 ±0	351 ±1867	0 ±0	12181 ±24646	11029 ±27388	1171 ±5756
Longline	331 ±544	0 ±0	0 ±0	0 ±0	0 ±0	7 ±35	0 ±0	0 ±0
Purse seine	18 ±544	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
Scuba dive	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0

Shark bycatch

Sharks had the highest bycatch of the three megafaunal groups. In longline fisheries, fishers reported 100% of mako shark bycatch, followed by blue shark. Fishers on artisanal and semi-industrial vessels mainly reported catching small, coastal shark species such as smooth hound, nurse and weasel sharks, whereas industrial vessels tended to catch larger, more pelagic species such as blue, mako and hammerhead sharks (Fig. 18). In addition, 91% of industrial fishers reported catching sharks as target species.

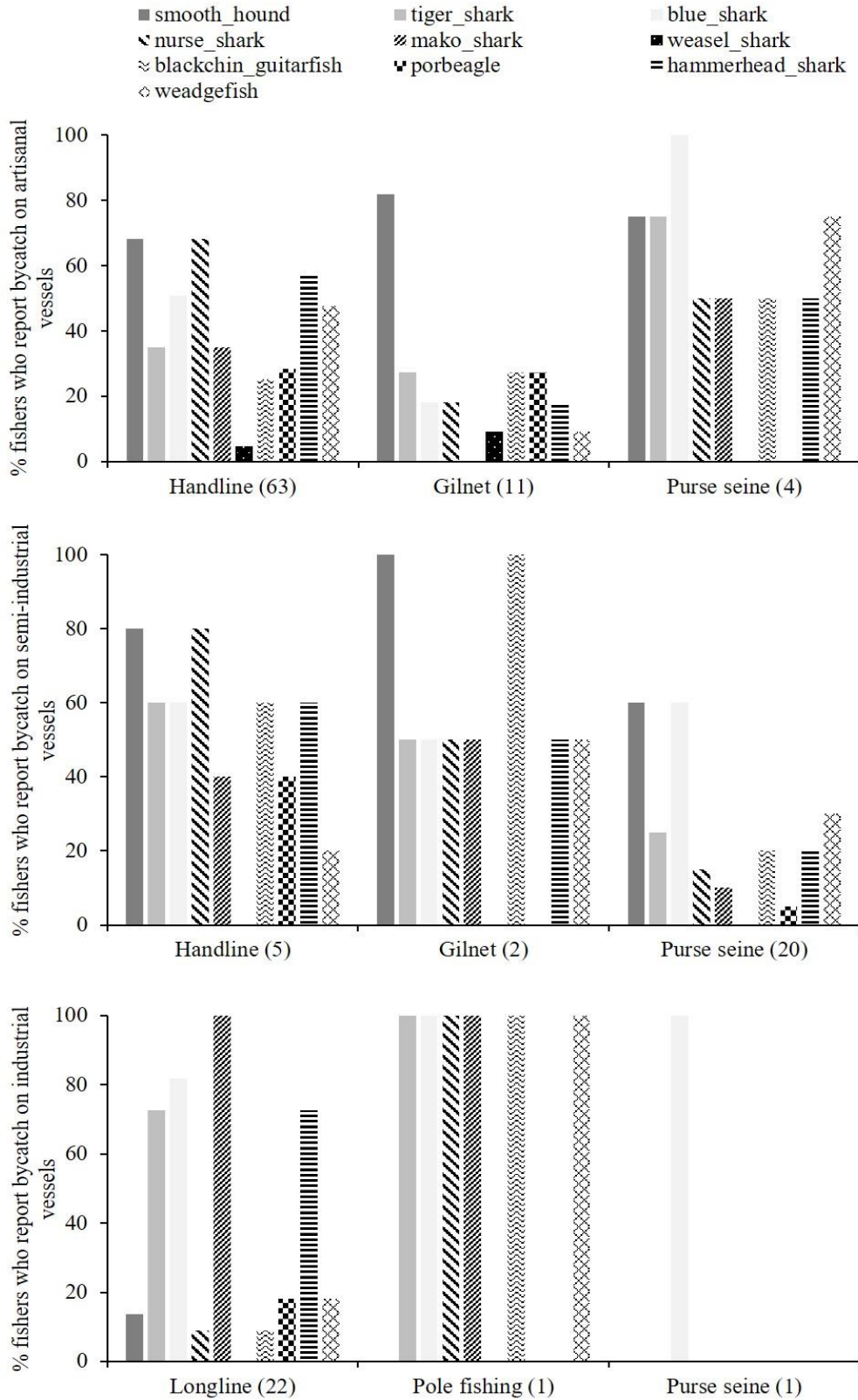


Fig. 18 Summary of shark's bycatch by different fishing gear operating in Cabo Verde waters, number in brackets mean the number of bycatches by each fishing gear on different vessels type.

Factors related to the amount of yearly shark bycatch

The best supported model for yearly shark bycatch was a zero inflated negative binomial model with the count model coefficient fishing area and zero-inflation model coefficient fishing gear (Table 14). In comparison to fishing outside of the Cabo Verde EEZ, fishing within the whole around Boavista Islet had significantly less shark bycatch (table 15). However, there were no significant differences with all other areas. Moreover, the model shows that the probabilities of false zeros (unreported or unobserved shark bycatch) insignificantly different between longline and other fishing gears (table 15).

Table 14. Model comparison for the shark’s bycatch. The best-fitting model is indicated in bold font. All models listed also included random effects for interview ID. The low Akaike Information Criterion (AIC) of the top model mean the best model

Model	Parameters	df	LogLik	AIC	w
ZINB_shark_3	fishing area + offset (fishing days per year) main fishing gear	13	-927.056	1882.7	0.919
ZINB_shark_2	main fishing gear + fishing area + offset (fishing days per year) main fishing gear	16	-926.182	1888.4	0.055
ZINB_shark	main fishing gear + fishing area + maximum distance to coast to fishing +offset (fishing days per year) main fishing gear	17	-925.623	1889.8	0.027
NB_shark	Fishing area + + offset (fishing days per year)	9	-943.352	1906.0	0.000

The mean bycatch of sharks per year varied strongly by species and by fishing gear. Among the common shark species in Cabo Verde waters, all were caught in large numbers except giant guitarfish by all vessel types (Fig 15). The reported monthly bycatch was also highly variable, suggesting that fishers using the same gear often declared different bycatch rates (Fig.15). When the mean annual number of sharks bycaught per fishing gear was extrapolated over the

number of vessels operating in Cabo Verde, the total number of sharks bycaught by handline was several magnitudes higher than in other fishing gears (Table 16).

Table 15. Summary of the results of the model investigating how the reported number of bycaught sharks per year related to whether fishers worked on different fishing gear. Estimates of fishing gear are calculated in relation to fishers from longline.

Fishing area / Fishing gear	Estimate	std. Error	Z value	Pr(> z)
Count model coefficients (negative binominal with log link)				
Intercept	6.6616	0.6342	10.504	<2e-16 ***
Brava, Fogo Island and Rombo Islet	-0.3485	0.6763	-0.515	0.6063
Cabo Verde EZZ area	-1.3710	0.7760	-1.767	0.0773 .
Northwest of Santo Antão	-0.4786	0.7761	-0.617	0.5375
Boavista Island	-1.4233	0.7146	-1.992	0.0464 *
Sal Island	0.9316	1.0351	0.900	0.3681
Santiago and Maio Island	-0.1772	0.7763	-0.228	0.8195
Sao Vicente, Santa Luzia and Sao Nicolau Island and Branco and Raso Islets	-1.2131	0.6749	-1.798	0.0722 .
Zero-inflation model coefficients (binominal with logit link)				
(Intercept)	-19.03	2887.44	-0.007	0.995
Handline	14.83	2887.44	0.005	0.996
Purse seine	18.25	2887.44	0.006	0.995
Gilnet	18.13	2887.44	0.006	0.995

Table 16. Estimation of the total annual sharks' bycatch per fishing gear type in Cabo Verde. Ranges indicate the mean and SD estimates

Main fishing gear	Smooth shark	Tiger shark	Blue shark	Nurse shark	Mako shark	Giant shark	Blackchin shark	Porbeagle shark	Hammerhead shark	Sicklefin shark
Fishing pole	0 ±0	150 ±300	150 ±300	75 ±150	150 ±300	0 ±0	150 ±300	0 ±0	0 ±0	150 ±300
Gillnet	3126 ±3153	581 ±1703	328 ±964	796 ±2263	379 ±1652	16 ±69	1165 ±2686	1137 ±2697	1137 ±2697	758 ±2270
Handline	73065 ±76741	29847 ±59191	36308 ±58935	55028 ±69903	27173 ±57052	859 ±4319	24088 ±56726	25767 ±56566	50402 ±70491	49348 ±73077
Longline	319 ±952	1662 ±1548	1799 ±1329	221 ±757	2302 ±1326	0 ±0	295 ±953	457 ±1134	1757 ±1556	322 ±952
Purse seine	4618 ±6362	1884 ±4448	3433 ±5058	582 ±2515	591 ±2521	0 ±0	1019 ±3355	369 ±2278	1515 ±4043	2894 ±5533
Scuba dive	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0

Discussion

This is the first widespread study assessing turtle, seabird and shark bycatch in the artisanal, semi-industrial and industrial fisheries operating in five islands in Cabo Verde. An alarming proportion of fishers from all sectors reported bycatch of these taxa, many of which are globally threatened. This suggests that megafaunal bycatch is widespread across Cabo Verde, and is prominent in many fishing sectors and gear types.

Artisanal fishers, principally those using handlines, purse seines and gillnets fishing gear, reported the highest proportion of bycatch, similar with the previous studies (Lee Lum, 2006; Peckham *et al.*, 2007, 2008; Jaramillo-Legorreta *et al.*, 2007; Mangel *et al.*, 2010). With over 5000 artisanal fishers and a fishing fleet of 1588 vessels in 2018, the artisanal fishery in Cabo Verde presents an important threat for marine ecosystems. We estimated that with handlines alone 20281 \pm 43842 turtles, 55497 \pm 90894 seabirds and 371886 \pm 583001 sharks are caught each year. However, the impacts of artisanal and semi-industrial fishers may be reduced by their tendency to release bycatch alive especially for turtles. While industrial fishers had more bycatch per vessel than in artisanal and semi-industrial fisheries, the fishing fleet is much smaller, resulting in lower sea turtle, seabird and shark bycatch numbers overall.

Among turtle species, loggerheads were the most commonly reported bycatch by all three groups of fishers. In previous studies in Maio, Boavista and Santiago Islands, artisanal and semi-industrial fishers also reported important loggerhead and green turtle bycatch (Monteiro, 2012, Lopes *et al.*, 2016). Lopes *et al.* (2016) found that a lower overall proportion of fishers reported turtle bycatch (32%) compared to my study (78%). However, their surveys were not anonymous so fishers may have been more reluctant to divulge turtle bycatch. Another possible cause for an increase in turtle bycatch is the increase in loggerhead nesting populations. In 2010 and 2012, Marco *et al.*, suggested that the North East Atlantic subpopulation of loggerhead

turtles was the second most endangered in the world and that Cabo Verde was the most important breeding area for this population with over 95% of the nests in the entire eastern Atlantic. However, since these studies the population and thus the global importance of nesting loggerhead turtles in Cabo Verde has increased significantly. Between 2012 and 2018, the number of identified nests in the archipelago increased from 29 thousand to 124 thousand, and recent data from DNA (DNA, September, 2020), already identified 180 thousand nests of loggerhead even without finish the season. This population increase can mainly be attributed to the protection of nesting females from poaching on land with effective legislation and the translocation of nests to nurseries to avoid predation by ghost crabs. Fishers also echoed this result as 66%, 64% and 66% reported an increase in interaction between turtles and fishing gear in the last 15, 10 and 5 years respectively.

The frequent bycatch of loggerhead turtles by artisanal and semi-industrial fishers can also be explained by the overlap between these vessels' fishing areas and the turtles' breeding areas. Boavista Island, which had 65% of this species nests in 2018 (DNA, 2018), was the area with the highest turtle bycatch both for artisanal and semi-industrial fisheries. In other regions where there are large numbers of breeding turtles, fishers also have reported high mortality rates (e.g. green turtles in Kenya; loggerhead in Tanzania and Mozambique; hawksbill turtles in Mauritius) (Kiszka, 2012). Prawn and shrimp trawl fisheries operating on the Sofala Bank off Mozambique catch an estimated 1 932 – 5 436 turtles annually (Gove *et al.*, 2001). Similar numbers are reported off Kenya, Madagascar and Tanzania, but more studies are needed to confirm the extent of bycatch in these countries (Bourjea *et al.*, 2008).

Green turtles, the second most commonly reported species, regularly feed in the coastal waters of Cabo Verde especially as juveniles, which can be found in relatively large numbers close to shore (Marco *et al.*, 2011). The frequent bycatch of these species by artisanal and semi-

industrial fishers can also be explained by the overlap between these vessels' fishing areas and the turtles' feeding areas (Marco *et al.*, 2011).

Leatherback turtles were also frequently reported as bycatch by industrial fishers. This is consistent with a previous study in Cabo Verde where industrial longliners also reported leatherback turtle bycatch (Melo & Melo, 2013). This species is largely pelagic, thus overlapping most with industrial fishing effort (> 13-18 nautical miles from the coast). Two areas with frequently reported bycatch, the northwest of Santo Antão and west of Boa Vista Island, are also important fishing areas above seamounts, thus increasing the possibility of turtle-fishery interactions (Worm *et al.*, 2003).

Regarding seabirds, Cape Verde shearwaters were the most frequently reportedly bycaught species by artisanal, semi-industrial fishers and industrial fishers within Cabo Verde waters, followed by brown boobies and red-billed tropicbirds. These 3 species are the largest seabird species of Cabo Verde, suggesting that there are morphological limitations of getting caught on certain gear types such as large hooks (Watson *et al.*, 2003, 2005). Worldwide, the most frequently caught species are also large (Croxall *et al.*, 2012). This can also explain why a higher number of seabirds are caught in artisanal vessels since the hooks used for handlines are generally smaller than those used for longlines.

Cape Verde shearwaters may be more frequently caught because of their high abundance during the breeding season (late February – late November) compared to the other seabirds in the archipelago (Paiva *et al.* 2015). Our results of where and when Cape Verde shearwaters are bycaught are also consistent with their breeding phenology and the location of their colonies. Breeding Cape Verde shearwaters change their foraging strategies during incubations and chick-rearing. While animals forage at the African shelf during incubation from June to July, they mainly forage in the waters surrounding their colonies during chick-rearing from August

to October (Paiva *et al.* 2015). This is consistent with the result that bycatch peaked in August and was mainly concentrated near major colonies in Raso islet and Boa Vista (Curral Velho Islet).

The temporal and spatial trends in brown booby and red-billed tropicbird bycatch are also consistent with their phenology and the distribution of nests. Unlike Cape Verde shearwaters, both species breed year-round, explaining why bycatch was consistent throughout the year. Moreover, large colonies of brown boobies and red-billed tropicbirds are located in Raso Islet, Boavista and Brava, where seabird bycatch was the highest (Semedo *et al.*, 2020)

Artisanal, semi-industrial and industrial fishers alike reported more shark bycatch than turtles or seabirds. This is consistent with the results of a previous study in Maio Island, where 71% of fishers reported sharks' bycatch in comparison to 32% who reported turtle bycatch (Lopes *et al.*, 2016). In addition, fewer than 20% of fishers reported releasing sharks alive, suggesting that shark mortality in Cabo Verde is extremely high. While approximately half of fisher's report that shark-fishery interactions have declined in the last 15 years because there are less sharks, few reported the need to protect sharks (67) in comparison to turtles (84) and seabirds (95). For artisanal and semi-industrial fishers, this perspective may be caused by shark-human conflict (Lopes *et al.*, 2016). During interviews, some fishers reported killing the sharks to avoid the repetitive loss of their fishing gear, bait or even their catches. However, some fishers also reported the sharks such as driving schools of prey to the surface making them available for fishers. Sharks are also the most used bycatch, with high proportions being used for food, to sell or as bait by artisanal, semi-industrial and industrial fishers. Furthermore, most fishers working on industrial vessels (91%) reported targeting sharks despite the fishery agreement between Cabo Verde and the European Union only being for tunas. According to Trindade-Santos *et al* (2012), foreign fleets operating within Cabo Verde EEZ declared 523, 590, 125,

331, 110 and 486 tonnes of shark bycatch while catching 493, 235, 326, 385, 199 and 383, tonnes of tuna from 1997 to 2002. This suggests that unregulated shark fishing in Cabo Verde is widespread and common and underlines the need for more active regulations.

The shark species reported by fishers is consistent with the distribution of sharks; while artisanal and semi-industrial fishers reported more bycatch of coastal species such as smooth hound and nurse sharks, industrial fishers reported bycatch of more pelagic species such as mako. Throughout the year, shark bycatch did not appear to vary based on the phenology of any specific species but instead peaked in the summer for all species. Although this may be due to the peak of two common prey species, bigeye scad and mackerel scad (*Decapterus macarellus*), this period also coincides with the period of highest reported fishing.

Although these results provide a good indication of the prevalence of turtle, seabird and shark bycatch in Cabo Verde, several limitations may have affected the results. For one, most fishers were aware that the capture of turtles and some shark species is illegal and may have been unwilling to declare the bycatch of these megafauna groups altogether in fear of persecution. Although there are no specific regulations preventing seabird bycatch, public awareness campaigns against seabird consumption and the fact that many important seabird colonies are located within marine protected areas where fishing is restricted (MAA & DGA, 2003) may also have resulted in fishers refusing to declare seabird bycatch. In addition, the lack of onboard observers in industrial fishing vessels (Melo & Melo, 2013) and restrictions at landing ports can limit the precise quantification of bycatch. Although I tried to limit this effect by conducting anonymous surveys and declaring that the interviews were not affiliated with any fishing organizations, some fishers may still have failed to declare accurate bycatch estimates. This may have caused some of the variability in the amount of bycatch declared by fisher's using the same gear type.

Species identification may also have been a limitation. Previous studies have found that fishers struggled to identify species, particularly seabirds (Brothers *et al.*, 2010; Zhou *et al.*, 2019) and sharks (Tillet *et al.*, 2012). However, fishers reported seasonal peaks in commonly caught species such as Cape Verde shearwaters and loggerhead turtles which matched their breeding periods and peak local abundance, suggesting that at least commonly caught species were correctly identified.

Moreover, since the last category quantifying bycatch was open ended (>9 individuals per month), estimates of bycatch may have been underestimated, particularly in the case of shark bycatch in industrial longline vessels reported targeting this group.

Low sample size of some fishing gears (such as beach net (1) and trawl (3)) or vessel type may be a limitation to detect the significance difference in the proportion of bycatch within groups or species.

Finally, the total estimated bycatch was simply calculated by extrapolating the amount of bycatch I recorded over all vessels using the same gear, irrespective of where these fishing vessels were operating from. Although this may not affect the results for semi-industrial and industrial bycatch since these vessels are wide-ranging, the amount of bycatch in artisanal vessels may be particularly affected by the proximity of their landing ports or beach to important turtle and seabird breeding areas. Since I focused fisher interviews in landing ports and beaches close to important turtle and seabird breeding areas, this extrapolation may have overestimated the total bycatch of these groups throughout Cabo Verde.

Although the results obtained from interviews are limited by the fishers' perceptions, their species identification skills and memory and the study design, they can provide useful insights into at least the relative extent of bycatch in an area and can help inform future observer, conservation and public awareness programs.

Management recommendations

Several species of conservation concern were identified as bycatch including Endangered loggerhead turtles, endemic Cape Verde shearwaters, and Critically Endangered great hammerhead. The high reports of bycatch of these species is of particular concern since their populations may not be able to sustain this additional source of mortality. Immediate actions are required to help offset the bycatch of these marine megafauna groups.

Several techniques and gear innovations can be used to reduce bycatch. In gillnet fisheries, using light emitting diode (LED) to illuminate nets at night has been found to reduce green turtle bycatch by 63% (Ortiz *et al.*, 2016). Fitting trawls with Turtle Excluder Devices (TEDs) and similar devices adapted to reduce turtle and shark bycatch have been shown to be effective (Epperly, 2003; Walker, 2005). In pelagic longlines, seabirds can be scared away from trying to take baited hooks with *tori* lines (Gilman, 2001; Melvin & Parrish 2001; Lokkeberg, 2003). As shown in my results, longline and handline were the fishing gears with the highest bycatch in all this megafauna groups. Therefore, bycatch mitigation should be directed towards these fisheries. Previous studies have found that changes to the equipment such as using circle hooks instead of J-hooks can reduce the frequency of deeply ingested hooks and consequently help to reduce bycatch mortality (Bolten *et al.*, 2003; Watson *et al.*, 2003, 2005; Promjinda *et al.*, 2008; Piovano *et al.*, 2010; Domingo *et al.*, 2012; Graves *et al.*, 2012). Circle hooks not only reduce turtle and shark bycatch, but can increase target catch, and thus can be readily adopted by fishers (Megalofonou *et al.*, 2005; Watson *et al.*, 2005; Yokata *et al.*, 2006). In addition, some fishing areas had more bycatch than others, suggesting that mitigation can be focused in high-impact areas. In particular, there was high rates of bycatch by artisanal fisheries in areas around integral reserves such as Rombos, Branco, Raso and Curral Velho Islets and Santa Luzia Island, suggesting that the current enforcement of legislation in these protected areas is insufficient. However, all these methods have at least an initial additional cost for them to be implemented. Public awareness campaigns and creative use of incentives endorsed by the governmental fisheries authority, with the support of Non-Governmental Organizations (NGOs), are required to effectively reduce bycatch in Cabo Verde fisheries. The fisheries authority needs to implement fisheries management practices such as accurate monitoring of fishery landings, as well as develop an onboard observer programme at least for industrial fisheries. Scientific data collection, processing and dissemination of findings has to be

prioritized, and in this regard the international fleet, operating under agreement with the EU, represents the easiest target for instituting an observer programme. Finally, there is a need to improve enforcement of national legislation and to use international policy initiatives to improve national regulations (e.g. CITES and the FAO National Plan of Action process).

In addition to gear innovations, spatial management techniques can also be used to reduce bycatch. The bycatch hotspots from this study may be used as a basis to locate important turtle, seabird and shark areas (feeding, breeding and/or foraging areas). In particular, the areas surrounding, Boa Vista, Santa Luzia and Brava Islands and Raso and Rombo Islets seem to be important areas for fishery-megafauna interactions. Combined with the breeding phenology of the main bycatch species such as loggerhead turtles and Cape Verde shearwaters, seasonal closures of bycatch hotspot areas can be an essential tool for spatial marine management of these species. In addition, as turtles, seabirds and sharks are marine top predators, they may also be indicators of biodiversity hotspots which should be considered conservation priorities (Worm *et al.*, 2003, Montevercchi *et al.*, 2012).

My data are the first to compare the bycatch of the three vessel types operating in Cabo Verde on five different islands across turtles, seabirds and sharks. I found that an artisanal fishery using handline is the dominant fishery in Cabo Verde, followed by a semi-industrial gillnet and purse-seine fishery and industrial longline. An alarmingly high proportion of fishers reported turtle, seabird and shark bycatch in all vessel types in Cabo Verde. While fishers reported higher amounts of bycatch per month in longline industrial vessels than artisanal or semi-industrial vessels, when extrapolated over the year and over the total number of vessels operating in Cabo Verde, artisanal vessels with handlines caught the highest amounts of turtles, seabirds and sharks. These results underline the impact of artisanal fisheries and the need to implement mitigation measures for bycatch in all vessel types.

Future studies should focus on combining observer data with more in-depth fisher surveys and tracking studies to understand the distribution and abundance of turtles, seabirds and sharks throughout the Cabo Verde EEZ and their interactions with fisheries. These studies may provide more accurate estimates of the bycatch and mortality rates, allowing us to identify the species-specific impact of bycatch in Cabo Verde.

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Appendixes

Appendix I – Questionnaire used during the survey

OPENING STATEMENT

Hello, my name is Gilson Montrond. I am an MSc student at the University of Cape Town, South Africa, and I am doing a survey on crew from artisanal and industrial fishing vessels to better understand the interaction between sea turtles, sharks and seabirds with fishing gear. Understanding the impacts of bycatch will help us to better manage marine resources and help us keep fish abundant for fishermen. The survey will take about 10-15 minutes. Would you be willing to participate? Thank you.

SECTION A – BACKGROUND INFORMATION

Questionnaire N° _____

Date: ____/____/2019

Interviewer:	Fisherman Id:
Island:	Age: <input type="checkbox"/> 18-30 <input type="checkbox"/> 31-50 <input type="checkbox"/> >50
Location:	Position: <input type="checkbox"/> Chief <input type="checkbox"/> Sailor <input type="checkbox"/> Scuba Diver <input type="checkbox"/> Other
Beach / Port:	Experience: _____
Group:	Boat type: <input type="checkbox"/> Artisanal <input type="checkbox"/> Industrial <input type="checkbox"/> Semi-Industrial

1. Do you come from a family of fishermen? Yes No
2. Is fishing the main way you earn your living? Yes No

If NO, what is/are your other occupations? _____.

3. At which months of the year do you usually fish? (Circle all months when you fish)

Lots of fishing J F M A M J J A S O N D

Little of fishing J F M A M J J A S O N D

No fishing J F M A M J J A S O N D

4. How many days do you go fishing each month?

Peak fishing month _____

Low fishing month _____

5. What is your monthly catch? (In kg)

Peak fishing month _____

Low fishing month _____

SECTION B – BOAT AND GEAR CHARACTERISTICS

6. How many boats do you work on? Artisanal ___ Industrial ___ Semi-Industrial ___
7. Boat features (I have two option in the case they work on more than one)

Potency (cv): _____	Crew number: _____	Length of the boat (m): _____
Potency (cv): _____	Crew number: _____	Length of the boat (m): _____

8. Fishing gear features. (Use illustrations)

Fishing gear	Artisanal	Industrial	Semi-Industrial	Hooks / nets size used to catch small fish	Hooks / nets size used to catch big fish	N° of Hooks settings	Gear size	Demersal/ Pelagic	when do you use it?	Small fish target species	Big fish target species
									J F M A M J J A S O N D		
									J F M A M J J A S O N D		
									J F M A M J J A S O N D		
									J F M A M J J A S O N D		
									J F M A M J J A S O N D		
									J F M A M J J A S O N D		
									J F M A M J J A S O N D		
									J F M A M J J A S O N D		

9. At which times of the day do you usually fish? (Make x)

Fishing gear/Time	6 hr-12hr	12hr – 18 hr	18 hr-00 hr	00 hr- 6 hr	All day

10. What time do you put fishing gear in the sea?

Fishing gear/Time	Sunrise	Day	Sunset	Night	All day

11. What time do you remove fishing gear in the sea?

Fishing gear/Time	Sunrise	Day	Sunset	Night	All day

12. Which areas do you usually fish in? (Indicate areas on map (use code).

Fishing gear	Areas (Use map/code)	Fishing gear depth	Distance from inshore

SECTION C – SEABIRD CATCHES

13. Do you ever catch seabirds accidentally? Yes No Intentionally? Yes No

14. If YES, on average how many in a month and annually (Record separate answer for each species)?

Species	Monthly				Annually			
	0	1-4	5-9	>10	0	1-4	5-9	>10
Cape Verde shearwater (<i>Calonnetris edwardsii</i>)								
Cape Verde Petrel (<i>Pterodroma feae</i>)								
Cape Verde band-rumped storm-petrel (<i>Hydrobates jabejabe</i>)								
Cabo Verde little shearwaters (<i>Puffinus lherminieri boydi</i>)								
Bulwer's petrel (<i>Bulweria bulwerii</i>)								
Brown booby (<i>Sula leucogaster</i>)								
Red billed tropicbird (<i>Phaethon aethereus</i>)								
White-faced storm-petrel (<i>Pelagodroma marina</i>)								

15. What is the main time of day to catch seabirds? (Make x)

6 hr-12 hr		12 hr-18 hr		18 hr-00 hr		00 hr-6 hr		All	
------------	--	-------------	--	-------------	--	------------	--	-----	--

16. When do accidental catches of seabirds occur?

When placed fishing gear at sea		When it is at sea		When removed from the sea	
---------------------------------	--	-------------------	--	---------------------------	--

17. How do seabirds get engaged in fishing gear?

18. Which species are caught on which gear? (Make x)

Species / Fishing gear	Longline	Handline	Trawler	Purse seine	Others
Cape Verde shearwater (<i>Calonetrus edwardsii</i>)					
Cape Verde Petrel (<i>Pterodroma feae</i>)					
Cape Verde band-rumped storm-petrel (<i>Hydrobates jabejabe</i>)					
Cabo Verde little shearwaters (<i>Puffinus lherminieri boydi</i>)					
Bulwer's petrel (<i>Bwulweria bulwerii</i>)					
Brown booby (<i>Sula leucogaster</i>)					
Red billed tropicbird (<i>Phaethon aethereus</i>)					
White-faced storm-petrel (<i>Pelagodroma marina</i>)					

19. What is the most three attractive type of bait for seabirds?

20. Which time of the year do you catch more? (Make x)

Species / Months	J	F	M	A	M	J	J	A	S	O	N	D
Cape Verde shearwater (<i>Calonetrus edwardsii</i>)												
Cape Verde Petrel (<i>Pterodroma feae</i>)												
Cape Verde band-rumped storm-petrel (<i>Hydrobates jabejabe</i>)												
Cabo Verde little shearwaters (<i>Puffinus lherminieri boydi</i>)												
Bulwer's petrel (<i>Bwulweria bulwerii</i>)												
Brown booby (<i>Sula leucogaster</i>)												

Red billed tropicbird (<i>Phaethon aethereus</i>)														
White-faced storm-petrel (<i>Pelagodroma marina</i>)														

21. What general location do you catch seabirds? _____ (Use map and cod)

22. If you catch a seabird, what do you do with it? (Circle your option)

Eat Sell Use as bait Discard (dead) Release (alive) Other _____

23. Have you seen a change in the number of seabirds you catch since you started fishing?

Yes No Don't know

If YES, what difference and why do you think so? _____.

24. Do you think seabirds are more abundant, less abundant or the same now compared to?

15 years ago? _____ 10 years ago? _____ 5 years ago? _____

If LESS or MORE, why do you think so? _____.

SECTION D – SEA TURTLE CATCHES

25. Do you ever catch sea turtles accidentally? Yes No Intentionally? Yes No

26. If YES, on average how many in a month and annually (Record separate answer for each species)?

Species	Monthly				Annually			
	0	1-4	5-9	>10	0	1-4	5-9	>10
Leatherback (<i>Dermochelys coriacea</i>)								
Hawksbill (<i>Eretmochelys imbricata</i>)								
Loggerhead (<i>Caretta caretta</i>)								
Green turtle (<i>Chelonia mydas</i>)								
Olive ridley (<i>Lepidochelys olivacea</i>)								

27. What is the main time to catch sea turtles? (Make x)

6 hr-12 hr		12 hr-18 hr		18 hr-00 hr		00 hr-6 hr		All	
------------	--	-------------	--	-------------	--	------------	--	-----	--

28. When do accidental catches of sea turtles occur?

When fishing gear placed at sea		When it is at sea		When removed from the sea	
---------------------------------	--	-------------------	--	---------------------------	--

29. How do sea turtles get engaged in fishing gear?

30. Which species are caught on which gear? (Make x)

Species / Fishing gear	Longline	Handline	Trawler	Purse seine	Others
Leatherback (<i>Dermochelys coriacea</i>)					
Hawksbill (<i>Eretmochelys imbricata</i>)					
Loggerhead (<i>Caretta caretta</i>)					
Green turtle (<i>Chelonia mydas</i>)					
Olive ridley (<i>Lepidochelys olivacea</i>)					

31. What is the most three attractive type of bait for sea turtles?

32. Which time of the year do you catch more? (Make x)

Species / Months	J	F	M	A	M	J	J	A	S	O	N	D
Leatherback (<i>Dermochelys coriacea</i>)												
Hawksbill (<i>Eretmochelys imbricata</i>)												
Loggerhead (<i>Caretta caretta</i>)												
Green turtle (<i>Chelonia mydas</i>)												
Olive ridley (<i>Lepidochelys olivacea</i>)												

33. What general location do you catch sea turtles? _____ (Use map and cod)

34. If you catch sea turtle, what do you do with it? (Circle your option)

Eat Sell Use as bait Discard (dead) Release (alive) Other _____

35. Have you seen a change in the number of sea turtles you catch since you started fishing?

Yes No Don't know

If YES, what difference and why do you think so? _____.

36. Do you think sea turtles are more abundant, less abundant or the same now compared to?

15 years ago? _____ 10 years ago? _____ 5 years ago? _____

If LESS or MORE, why do you think so? _____.

SECTION E – SHARK CATCHES

37. Do you ever catch sharks accidentally? Yes No Intentionally? Yes No

38. If YES, on average how many in a month and annually (Record separate answer for each species)?

Species	Monthly				Annually			
	0	1-4	5-9	>10	0	1-4	5-9	>10
Smooth-hound shark (<i>Mustelus mustelus</i>)								
Tiger shark (<i>Galeocerdo cuvieri</i>)								
Blue shark (<i>Prionace glauca</i>)								
Nurse shark (<i>Ginglymostoma cirratum</i>)								
Mako shark (<i>Isurus oxyrinchus</i>)								
Wedgefish (<i>Rhynchobatus</i> spp.)								
Blackchin guitarfish (<i>Glaucostegus cemiculus</i>)								
Porbeagle (<i>Lamna nasus</i>)								
Hammerheads (<i>Sphyrna</i> spp.)								
Atlantic weasel shark (<i>Paragaleus pectoralis</i>)								

39. What is the main time to catch sharks? (Make x)

6 hr-12 hr		12 hr-18 hr		18 hr-00 hr		00 hr-6 hr		All	
------------	--	-------------	--	-------------	--	------------	--	-----	--

40. When do accidental catches of sharks occur?

When placed at sea		When it is at sea		When removed from the sea	
--------------------	--	-------------------	--	---------------------------	--

41. How do sharks get engaged in fishing gear?

42. Which species are caught on which gear? (Make x)

Species / Fishing gear	Longline	Handline	Trawler	Purse seine	Others
Smooth-hound shark (<i>Mustelus mustelus</i>)					
Tiger shark (<i>Galeocerdo cuvieri</i>)					
Blue shark (<i>Prionace glauca</i>)					
Nurse shark (<i>Ginglymostoma cirratum</i>)					
Mako shark (<i>Isurus oxyrinchus</i>)					
Wedgefish (<i>Rhynchobatus</i> spp.)					

Blackchin guitarfish (<i>Glaucostegus cemiculus</i>)					
Porbeagle (<i>Lamna nasus</i>)					
Hammerheads (<i>Sphyrna</i> spp.)					
Atlantic weasel shark (<i>Paragaleus pectoralis</i>)					

43. What is the most three attractive type of bait for sharks?

44. Which time of the year do you catch more? (Make x)

Species / Months	J	F	M	A	M	J	J	A	S	O	N	D
Smooth-hound shark (<i>Mustelus mustelus</i>)												
Tiger shark (<i>Galeocerdo cuvieri</i>)												
Blue shark (<i>Prionace glauca</i>)												
Nurse shark (<i>Ginglymostoma cirratum</i>)												
Mako shark (<i>Isurus oxyrinchus</i>)												
Wedgefish (<i>Rhynchobatus</i> spp.)												
Blackchin guitarfish (<i>Glaucostegus cemiculus</i>)												
Porbeagle (<i>Lamna nasus</i>)												
Hammerheads (<i>Sphyrna</i> spp.)												
Atlantic weasel shark (<i>Paragaleus pectoralis</i>)												

45. What general location do you catch sharks? _____ (Use map and code)

46. If you catch a shark, what do you do with it? (Circle your option)

Eat Sell Use as bait Discard (dead) Release (alive) Other _____

47. Have you seen a change in the number of sharks you catch since you started fishing?

Yes No Don't know

If YES, what difference and why do you think so? _____.

48. Do you think sharks are more abundant, less abundant or the same now compared to?

15 years ago? _____ 10 years ago? _____ 5 years ago? _____

If LESS or MORE, why do you think so? _____.

SECTION F - PERCEPTION AND PARTICIPATION

49. Do you think we should be concerned about the future of seabirds?

Yes No Don't know

If YES, why do you think so? _____.

50. Do you think we should be concerned about the future of sea turtles?

Yes No Don't know

If YES, why do you think so? _____.

51. Do you think we should be concerned about the future of sharks?

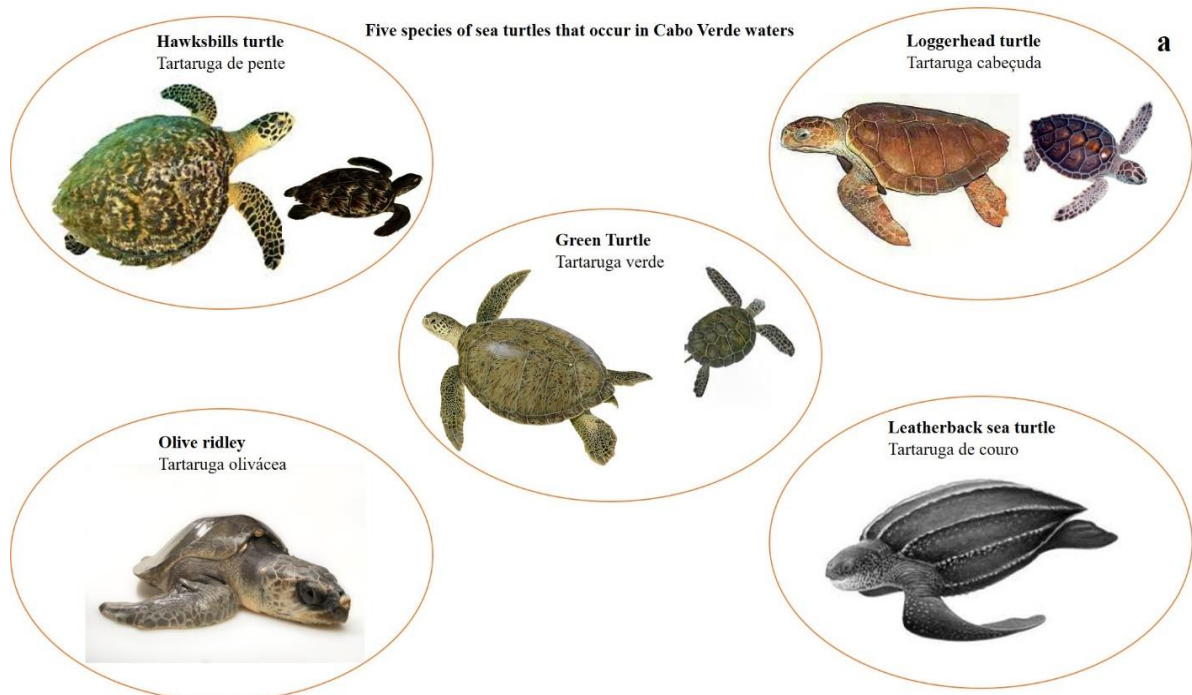
Yes No Don't know

If YES, why do you think so? _____.

52. Would you want to be consulted or involved in government and NGOs initiatives for the conservation of these species? YES NO

High Medium Low

Appendix II - Field guide to the marine megafauna that occur in Cabo Verde waters used during the surveys; a - turtles; b – seabirds and c – sharks (Source: NOAA Fisheries)





b



Smooth hound shark
O cão de caça liso



Blue shark
Tubarão Azul



Blackchin guitarfish
Tubarão violão de queixo preto



Nurse sharks
Tubarão Gata; Tubarão-enfermeiro; Tubarão-lixia; Lambaru.



Giant guitarfish
Peixe gigante ou Peixe-espada branco

c



Tiger shark
Tubarão tigre



Mako-shark
Tubarão mako; Tubarão mako-cavala



Sicklefin weasel shark
Tubarões doninha



Blacktip
Tubarão Sardo ou barrilote Sardo Canexo
NC: *Lamna nasus*