Received: 20 February 2024 | Revised: 25 April 2024 | Accepted: 15 May 2024

DOI: 10.1002/aqc.4206

ARTICLE

WILEY

Baseline assessment of the coastal elasmobranch fauna of Eastern Cabo Verde, West Africa

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Funding information
The research was financially supported by The Ocean Foundation, the Mitchell-Peterson Family Foundation, the Wildlife Conservation Network and the Houston Zoo.

Abstract

An increasing onus on elasmobranch management by regional bodies has been hindered by a lack of data on abundance, distribution and fisheries, especially in data-poor areas like the eastern Atlantic Ocean. From 2015 through 2017, 204 baited remote underwater videos (BRUV) were deployed in Cabo Verde around the eastern islands of Sal, Boavista and Maio and the remote offshore reef João Valente to establish a baseline of elasmobranch abundance. Over 200 hours of footage revealed 215 individual elasmobranchs, spanning 14 species from 6 taxonomic families. The abundance of elasmobranchs was highest in Maio, the island with the smallest human population, followed by Boavista and Sal. Smaller-bodied meso-predatory species such as the common smoothhound (*Mustelus mustelus*) and the Atlantic weasel shark (*Paragaleus pectoralis*) constituted the majority of observations in Maio and Boavista. Inversely, *Carcharhinus* spp. were observed in considerably greater abundance in Sal, and there was notably lower abundance of small-bodied sharks at sites with high large-bodied Carcharhinid abundance. Species richness was consistent with abundance estimates across islands, with Boavista and Sal recording the highest species diversity, followed by Maio. Results suggest that amongst Cabo Verde's eastern islands, there exists a high relative diversity and abundance of coastal elasmobranchs compared to populations in West Africa. Nonetheless, there is evidence of exploitation of higher trophic levels species. This trend is most notable in the decreasing abundance of Carcharhinids with increasing proximity to the capital city Praia, suggesting that fishing efforts from the capital are negatively affecting the abundance of large-bodied, higher-trophic predators.

KEYWORDS

BRUV, Carcharhinidae, Dasyatidae, Ginglymostomatidae, marine conservation, marine megafauna, Mobulidae, Triakidade

Zeddy T. A. Seymour and Ze Luis Monteiro, Deceased.

1 | INTRODUCTION

In the last century, the intensive exploitation of elasmobranchs by targeted fisheries and high levels of mortality in other fisheries as bycatch (Filmalter et al., 2013; Musick et al., 2000) have significantly reduced global populations, resulting in over a third of all known species being currently classified as threatened (vulnerable, endangered or critically endangered) according to the International Union for the Conservation of Nature (IUCN) criteria (Dulvy et al., 2021). Such broad-scale population declines are of growing concern, as elasmobranchs are widely attributed to play important roles in healthy ecosystem functioning (Baum & Worm, 2009; Ferretti et al., 2010; Roff et al., 2016) and are increasingly recognized for their economic value in the tourism industry (Cisneros-Montemayor et al., 2013; Topelko & Dearden, 2005); However, in certain regions, a lack of broad-scale baseline data has impeded understanding of population trends and prevented effective management (Carneiro, 2012).

The Republic of Cabo Verde is one such region where very little basic data for elasmobranchs is available, and management measures are minimal. This volcanic archipelago is located approximately 600 km west of Senegal (N14°50′-17°20′, W22°40–25°25′), in an area of the Atlantic Ocean known as the Eastern Central Atlantic (ECA). The ECA, identified as a hotspot for marine biodiversity (Roberts et al., 2002), is a vast area between Mauritania and Angola encompassing the Exclusive Economic Zones (EEZs) of more than 20 countries from Europe to Sub-Saharan Africa. This region also has one of the highest rates of illegal and unreported fishing (IUU) globally (Agnew et al., 2009; Carneiro, 2012). As a result, many elasmobranch species throughout the ECA are thought to be in decline or, in the case of particularly sensitive species, already 'decimated' (Diop & Dossa, 2011). Of the 137 elasmobranch species recorded in the ECA (Polidoro et al., 2017), 27% are considered data deficient and over 50% are classified as threatened or near threatened (IUCN, 2024).

Cabo Verde has the highest level of marine biodiversity in the ECA (Polidoro et al., 2017; Wirtz et al., 2013) and stands out among the Macaronesian archipelagos for the high diversity and endemism of marine species found here (Freitas et al., 2019). Cabo Verde also remains the one area in the ECA where elasmobranchs are unlikely to be fully exploited by fisheries (Diop & Dossa, 2011), though fishing effort (particularly from European fleets) has increased in the past two decades and may be driving overfishing of some pelagic elasmobranch species (Coelho et al., 2020). The insular waters are believed to support a wide variety of resident and migratory species; however, studies of the Caboverdean marine fauna have thus far been limited to descriptions of species assemblages in different parts of the archipelago (Menezes & Fernandes, 2004; Monteiro et al., 2008; Vieira et al., 2018) with no reference to their relative or absolute abundance. In-country targeted shark fisheries are thought to be considerably less developed than those of other countries in the ECA (Diop & Dossa, 2011), in part due to legislation prohibiting the act of finning at sea (Resolução n° 56/2014 of 31 July, BO n° 18-Serie I; Diop & Dossa, 2011). Most shark species are rarely targeted in Cabo Verde, with the exception of cação, which generally refers to dried and salted meat from *Mustelus mustelus*, but also includes juveniles of larger species, and is widely consumed during the Christmas and Easter holiday seasons. Overall, sharks' contribution to annual local landings has historically been considered negligible (Gominho et al., 2006); however, artisanal fisheries are poorly regulated, and underreporting is widespread. Data from surveyed artisanal fishers indicated they have experienced significant declines in the numbers of elasmobranchs in recent history. Additionally, in recent years, reported landings from European Union vessels operating in the EEZ of Cabo Verde (under agreements between the European Community and Cabo Verde) have been dominated by sharks (Diop, 2014), and there are signs that some species may be now overfished (Coelho et al., 2020).

The waters around the eastern islands of Sal, Boavista and Maio have some of the highest levels of biological productivity in the archipelago and contain some of the most productive and least exploited fishing grounds (Carneiro, 2012; Fernandes et al., 2005). Nonetheless, pressure on marine resources is rising (Lima & Martins, 2010) due to the increasing translocation of fishers from other islands, as well as the recent boom in mass tourism, both of which are driving rapid human population growth (Benchimol et al., 2009; Brito et al., 2024; López-Guzmán et al., 2013). Such emergent threats highlight the need for quantitative assessments of the distribution, abundance and trends of marine resources, including sharks and other charismatic megafauna, and their contributions to livelihoods (Lack & Sant, 2009; Simpfendorfer et al., 2011; Worm et al., 2006; Yoccoz et al., 2001).

Baited remote underwater video (BRUV) can provide a fishery-independent standardized method to assess biodiversity, abundance and species distribution of marine megafauna and is increasingly used to survey highly mobile elasmobranchs (Brooks et al., 2011; Clarke et al., 2012; White et al., 2013). Studies have shown BRUVs to generate a catch per unit effort (CPUE) estimate comparable to other traditional methods used to survey elasmobranchs (e.g. scientific longline Santana-Garcon et al., 2014), and the relatively non-invasive technique is appropriate for use in marine protected area (MPA) monitoring as well as with species of conservation concern (White et al., 2013). Furthermore, BRUVs provide a cost-effective method that can be relatively easily replicated while removing the need for specialist observers in the field.

In this study, BRUVs were employed to obtain information on the elasmobranch populations of eastern Cabo Verde and create a baseline assessment that can underpin future management of these populations. The objectives of the study were to 1) construct a baseline of elasmobranch relative abundance and distribution for eastern Cabo Verde; 2) identify key sites of abundance; 3) identify factors influencing the abundance of species in the eastern islands and 4) form the basis of long-term management and feed into conservation strategies with a focus on threatened and data deficient species and their critical habitats.

2 | METHODS

2.1 | Baited Remote Underwater Video

Surveys were focused on the three easternmost islands of the archipelago: Maio, Boavista and Sal. These islands, particularly Boavista and Maio, are linked by shallower bathymetry and have been found to host a similar species assemblage that is distinct from that of other islands in the archipelago (Medina et al., 2007). The other major islands of the archipelago could not be surveyed in this study. Between 2015 and 2017, 204 mono BRUV replicas were deployed at fixed stations around the islands of Boavista (April and May 2015, $n = 67$), Sal (June–July 2016, $n = 63$) and Maio (May–June 2016, $n = 59$), also including the offshore reef of João Valente (September 2017, $n = 15$; Figure 1). Stations were chosen with the aim of obtaining as homogenous a cover of the coastal area of the islands as possible and to provide ease of replication. Stations were hence positioned 5 km apart around the circumference of each island, at three or four depth strata between 1 m and 60 m when possible (Figure 1). A small subset of locations ($n = 15$) did not follow this design and were placed in a haphazardly random manner around the João Valente reef and at additional locations to maximize the habitat and depth stratification. All stations were surveyed once. All replicas utilized a standardized methodology (Graham et al., 2012), allowing direct comparison among sites, habitats and across time. Standard soak time was a minimum of 65 minutes, and 1.0 kg of crushed oily bait (usually Frigate tuna, *Auxis thazard*) was placed in a receptacle that extended 1.0 m from the frame and was positioned 70 cm off the sea floor in front of a singular horizontal-facing camera (GoPro TM). A 30 cm t-bar at the end of the bait cage allowed for the estimation of sizes for animals that approached the cage and were viewed laterally.

All videos were reviewed in regular speed playback by at least 2 trained observers. Video review began five minutes after the BRUV settled on the sea floor, to allow the boat to depart the area and the habitat to return to an 'undisturbed state'. Videos were reviewed in total, but only the subsequent 60 minutes were then analysed for elasmobranch presence. All elasmobranch observations were recorded and identified to the lowest taxonomic level achievable. Coarse habitat was defined according to the dominant benthic substrate: sand, rock, rocky reef or algae. Species were categorized into groups based loosely on taxonomy and trophic function: Carcharhinid sharks, non-Carcharhinid sharks, benthic rays and mobula rays. For each deployment, two metrics were recorded for each species encountered: 1) the sequential N, defined as the total

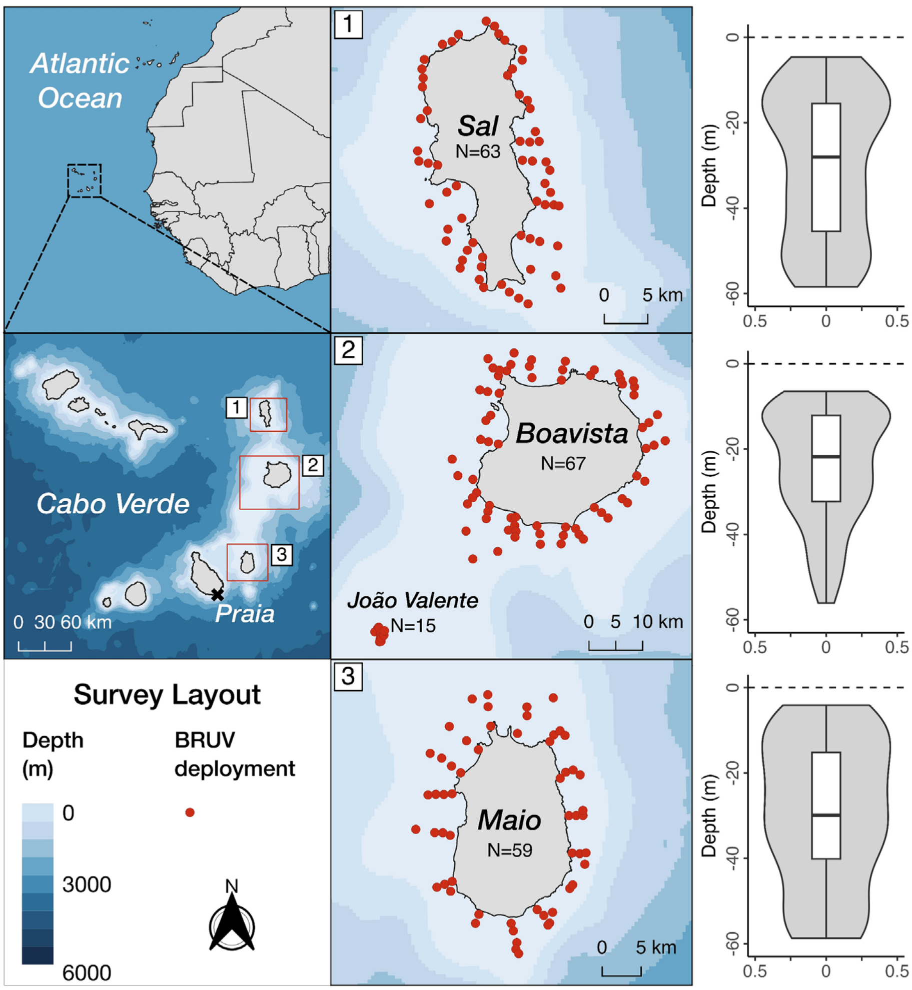

FIGURE 1 Locations of BRUV replicas deployed in Cabo Verde from 2015 to 2017. (Left panel) The location of the study sites in the archipelago of Cabo Verde is indicated by red rectangles. (Middle panel) Red dots indicate single BRUV deployments, the total number of BRUVs deployed at each site is indicated by N. (Right panel) Depth distribution of BRUV deployments at each island summarized by quantiles (white box, horizontal lines indicate 25%, 50% and 75% quantiles) and density (grey polygons).

number of individuals belonging to the species sighted during the 60 minutes, and 2) MaxN, the maximum number of individuals sighted in the same frame at any time (Cappo et al., 2003; Willis & Babcock, 2000).

2.2 | Data analysis

Four estimates were calculated for each species or species group across all deployments: 1) mean N; 2) mean MaxN; 3) Relative abundance (RA), calculated as the sum of MaxN per species and species group across all BRUVs divided by the total number of BRUVs deployed and 4) percent frequency of occurrence (%FO), defined as the number of BRUVs where target species were sighted divided by the total number of BRUVs deployed times 100. N, MaxN, RA and %FO were also calculated separately for each island.

To assess differences in elasmofauna by location (island), species diversity indices were calculated using Shannon's diversity index (H′) (Hill, 1973). Species accumulation curves were examined to assess whether shark species assemblages were adequately described at both the island and the study-region levels.

To explore the spatial structure of sightings, the kernel density distribution of BRUV deployments weighted by MaxN values recorded at each deployment was calculated in QGIS (version 3.10; QGIS Development Team, 2020). A radius of 10 km was chosen for all kernels because it best represented the underlying spatial structure of the data. Kernel densities were also calculated and plotted for species groups separately.

Generalized linear models (GLMs) were used to assess factors influencing the abundance of species groups (Non-Carcharhinids, Carcharhinids and benthic rays) and for individual species where MaxN>20. If overdispersion was detected, a GLM with a negative binomial error distribution was used, otherwise, a GLM with a Poisson error distribution was applied to the count data (MaxN) (Zuur et al., 2009), where the full model was: MaxN $\sim$ Depth $+$ Latitude $+$ Protected status (protected vs. unprotected) $+$ Habitat. Given the north–south distribution of the islands surveyed in the study, latitude was deemed an appropriate variable to investigate gradients in the abundance of elasmobranch groups across the entire study region. Depth and Habitat were included as they are known to influence the abundance of coastal species (e.g. Lester et al., 2022; Tickler et al., 2017), and Protected status was included to assess the efficacy of existing marine protected area in bolstering elasmobranch abundance. Model selection was based on AIC selection criteria, with the final model having the lowest AIC (Zuur et al., 2009). Nurse sharks were excluded from the grouped GLM of non-Carcharhinid sharks as it was the only shark species sighted at all three island locations and also João Valente; Therefore, its abundance was not representative of the other smaller-bodied species. Final selected models were compared to the full model using analysis of deviance (Chi-square tests) and were kept only if they were significantly better than the full model.

Total length (TL ± 0.3 m) was visually estimated for sharks that approached the 30 cm t-bar and could be fully viewed laterally. Length-frequency distributions were plotted by island for species where more than one size estimate was made. The approximate size at maturity for each species was denoted on each plot using published estimates (Ba et al., 2013; Branstetter, 1987; Brown & Gruber, 1988; Capapé et al., 2006; Castro, 1996; Castro, 2000; Natanson et al., 2023; Saïdi et al., 2008).

Linear models and diversity indices were performed using Program R (R Core Team, 2023), with the packages pscl, MASS, and vegan (Oksanen et al., 2017; Venables & Ripley, 2002; Zeileis et al., 2008), and the tidyverse packages were used throughout analyses (Wickham, 2009; Wickham, 2017).

3 | RESULTS

All but one of the deployed BRUVs successfully recorded video, yielding a total of 203 hours of video footage that could be analysed. Across all BRUVs, a total of 215 individual elasmobranchs were recorded (Table 1). The species accumulation curve indicated that species richness was sufficiently described overall (Figure 2a), while curves did not appear to reach asymptotes at Sal and Maio when broken down by island (Figure 2b). Across all four locations, 14 different species were sighted: smoothhound (*M. mustelus*); Atlantic weasel shark (*Paragaleus pectoralis*); round fantail stingray (*Taeniurops grabata*); nurse shark (*Ginglymostoma cirratum*); spinner shark (*Carcharhinus brevipinna*); blacktip shark (*C. limbatus*); milk shark (*Rhizoprionodon acutus*); lemon shark (*Negaprion brevirostris*); sickle fin mobula ray (*Mobula tarapacana*); roughtailed stingray (*Bathytoshia centroura*); tiger shark (*Galeocerdo cuvier*); dusky shark (*C. obscurus*) and barbeled houndshark (*Leptocharias smithii*), listed from most to least abundant. Six individual sharks were identified to the genus Carcharhinus and one to the family Triakidae, but species-level identification was not possible from the footage.

Non-Carcharhinid sharks were the most abundant species group overall (Table 1, Figure 3a,b), with the smoothhound being the most abundant species (MaxN $=$ 49, RA $=$ 0.24, FO $=$ 12.70%), followed by the Atlantic weasel shark (MaxN $=$ 31, RA $=$ 0.51, FO $=$ 13.2%), round fantail stingrays (MaxN $=$ 31, RA $=$ 0.51, FO $=$ 12.70%) and nurse sharks (MaxN $=$ 24, RA $=$ 0.12, FO $=$ 10.80%) (Table 1, Figure 3a,b). Maio exhibited the highest abundance (MaxN $=$ 70, RA $=$ 1.23), followed by Sal (MaxN $=$ 54, RA $=$ 79.37) and Boavista (MaxN $=$ 54, RA $=$ 78.26) (Table 1). Species diversity was highest at Boavista (H′ $=$ 2.21), followed by Sal (H′ $=$ 1.97), Maio (H′ $=$ 1.59) and João Valente (H′ $=$ 0.90).

Non-carcharhinid sharks were found at all islands surveyed, but were particularly abundant at Maio, Boavista and João Valente, while Carcharhinid sharks were the most abundant species group at Sal (Figures 3 and 4). Benthic rays also occurred at all monitored islands and were especially abundant at the offshore reef João Valente, where nurse sharks were also highly abundant (Figures 3 and 4). Generally, a latitudinal gradient in species composition could be

TABLE 1 Species composition of elasmobranchs observed across all BRUV recordings at Cabo Verde from 2015 to 2017. Species are grouped into broad categories by size and trophic level. N is the total number of species sighted, MaxN is the sum of the maximum number of each species sighted in a frame at the same time, RA is relative abundance (MaxN/total BRUVs deployed) and %FO is the percent frequency of occurrence (number of BRUVs each species occurred on/total BRUVs deployed).

		Sal				Boavista				João Valente				Maio			
Category	**Common name**	**N**	**MaxN**	**RA**	**%FO**	**N**	**MaxN**	**RA**	**%FO**	**N**	**MaxN**	**RA**	**%FO**	**N**	**MaxN**	**RA**	**%FO**
Non-Carcharhinid shark	Atlantic weasel shark					16	14	0.20	17.39					17	17	0.30	26.32
	Barbeled houndshark					1	1	0.01	1.45								
	Milk shark	1	1	0.02	1.59	6	6	0.09	7.25					1	1	0.02	1.75
	Nurse shark	3	3	0.05	4.76	4	4	0.06	5.80	13	9	0.60	46.67	8	8	0.14	14.04
	Smoothhound	14	12	0.19	9.52	6	6	0.09	8.70					34	31	0.54	24.56
	Triakidae					1	1	0.01	1.45								
Carcharhinid shark	Blacktip shark	3	3	0.05	4.76	4	4	0.06	4.35					1	1	0.02	1.75
	Carcharhinidae	1	1	0.02	1.59	4	3	0.04	4.35					1	1	0.02	1.75
	Dusky shark					1	1	0.01	1.45								
	Lemon shark	3	2	0.03	3.17	2	2	0.03	2.90					1	1	0.02	1.75
	Spinner shark	15	13	0.21	19.05	4	4	0.06	5.80					2	2	0.04	3.51
	Tiger shark	3	3	0.05	4.76												
Benthic ray	Roughtailed stingray	1	1	0.02	1.59	2	2	0.03	2.90								
	Round fantail stingray	14	13	0.21	17.46	7	6	0.09	8.70	9	7	0.47	33.33	5	5	0.09	7.02
Mobula ray	Mobula ray	1	1	0.02	1.59					2	2	0.13	13.33				
	Sicklefin mobula ray	1	1	0.02	1.59									3	3	0.05	1.75
Total		**60**	**54**	**0.86**	**71.43**	**58**	**54**	**0.78**	**72.46**	**24**	**18**	**1.20**	**93.33**	**73**	**70**	**1.23**	**84.21**

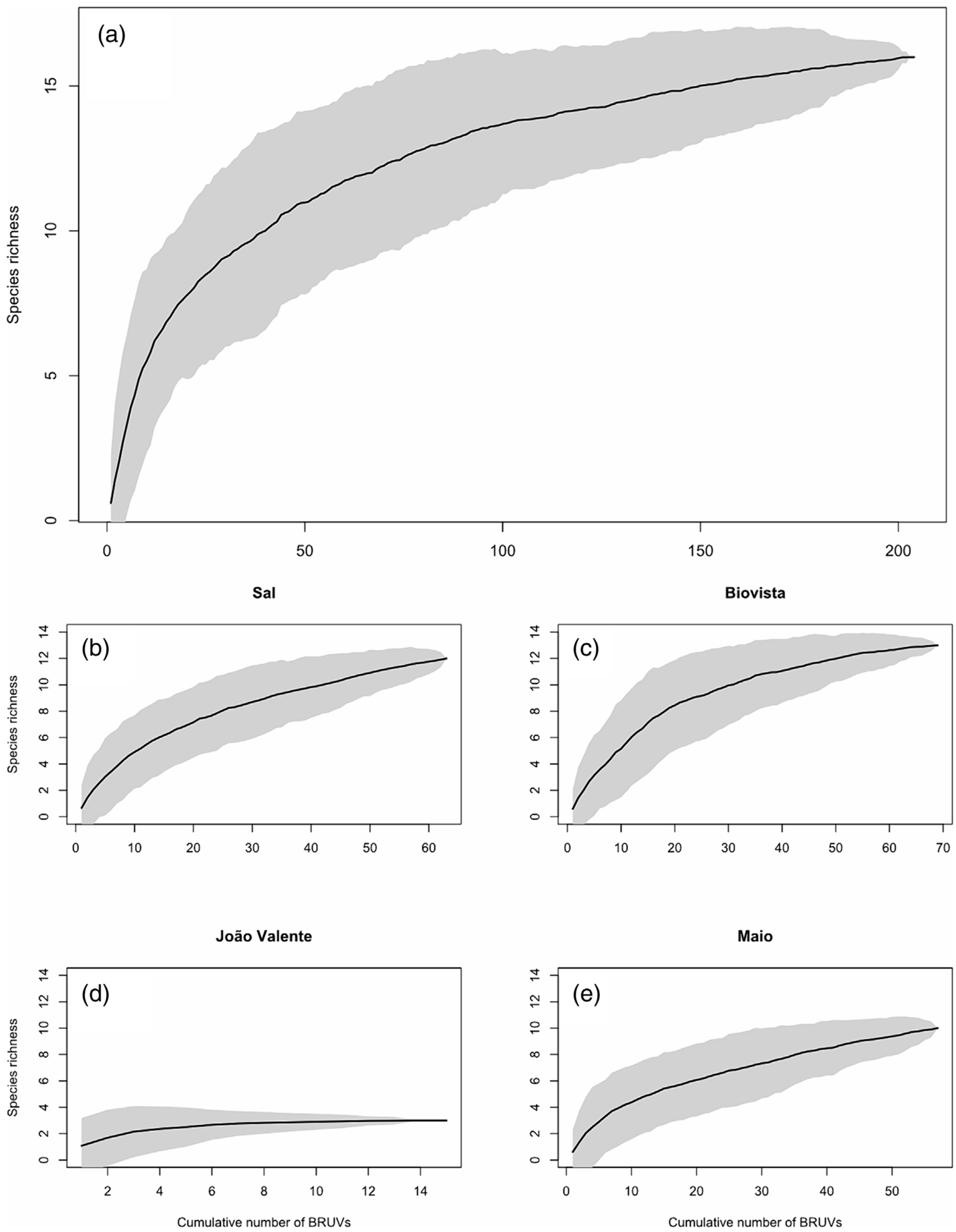

FIGURE 2 Species accumulation curves. Cumulative number of species detected (black line) and standard deviation (grey shading) for the cumulative number of BRUVs (a) overall, and (b–e) by island.

observed, with large-bodied shark apex predator (Carcharhinids) abundance decreasing from north to south, and small-bodied/mesopredatory shark (non-Carcharhinid) abundance following the opposite trend (Figure 4). Mobula rays were sighted in small numbers at Sal, João Valente and Maio, but not at Boavista. Within islands, the east coast of Sal stood out as a key area for elasmobranch abundance, driven predominantly by sightings of Carcharhinid sharks (Figure 4). The north-east and north-west coasts of Maio and João Valente also had a high density of sightings. The west coast of Sal and the south-east coast of Boavista seemed to host the lowest abundance of sightings, a trend observed for all species groups.

Generalized linear models indicated that the abundance of the species groups was influenced by a restricted subset of factors. Latitude was the only factor found to significantly influence the abundance of all three elasmobranch groups, while habitat type was found to influence the abundance of Carcharhinids and benthic rays, and depth was also found to have a significant effect on the abundance of non-Carcharhinid sharks, excluding nurse sharks

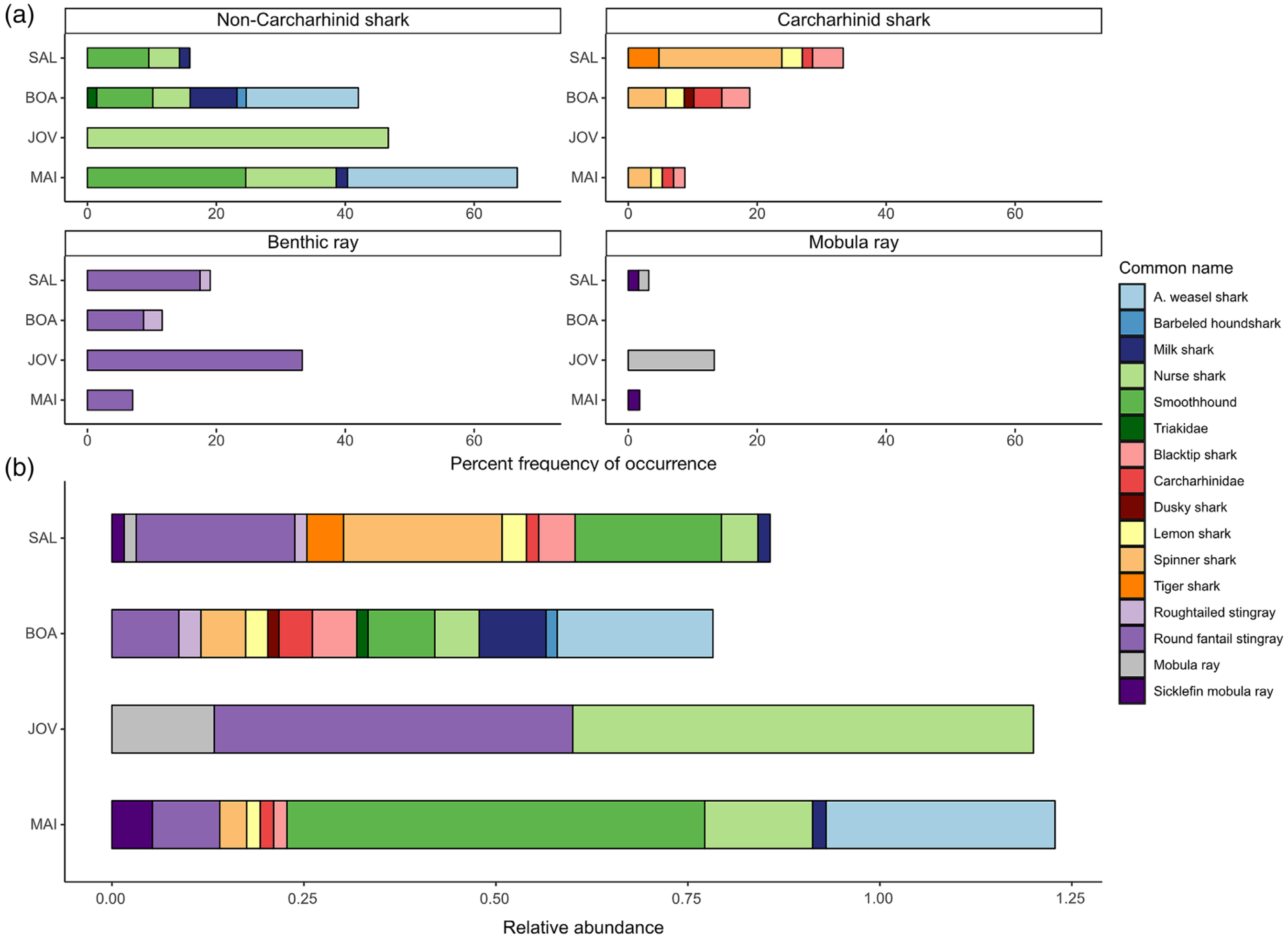

FIGURE 3 Species composition and abundance of elasmobranchs in eastern Cabo Verde. (a) Frequency of occurrence of all sighted species (percentage of BRUVs where each species was sighted) per island (from north to south: SAL = Sal, BOA = Boavista, JOV = João Valente, MAI = Maio), separated by species group. (b) Relative abundance (N° of sightings/BRUVs deployed) of each species by island.

(Table 2). Clear differences were observed between groups with respect to the effect of latitude on abundance: while the abundance of Carcharhinid sharks and benthic rays was positively affected by increasing latitude, a strong negative effect of latitude was observed for non-Carcharhinids (Table 2). The protected status of a site was found to have a negative influence on the abundance of Carcharhinids and benthic rays and a positive effect on non-Carcharhinids, though its effect was not statistically significant. In single-species models, latitude was found to be a significant factor only for smoothhound and round fantail stingray, with smoothhound abundance strongly decreasing with increasing latitude (i.e. from Maio to Sal). The abundance of nurse sharks and round fantail stingrays was instead more strongly affected by habitat type (Table 2).

Sizes were estimated for nine species of sharks, with a total of 96 estimated measurements (Figure 5). In all, 76% of sharks for which measurements were estimated were juveniles. All spinner ($n = 10$), tiger ($n = 3$) and nurse sharks ($n = 22$) were under the size at maturity, while between 54 and 76% of Atlantic weasel ($n = 26$), blacktip ($n = 6$), lemon ($n = 4$), milk ($n = 8$) and smoothhound sharks ($n = 17$) were determined to be juveniles (Figure 5).

4 | DISCUSSION

Results from this study showed a high occurrence, relative abundance and diversity of shark and ray species at the eastern islands of Cabo Verde, with a total of 14 species identified in these three islands alone. While surveys could only be conducted once in each island, and so may have missed seasonal residents, accumulation curves suggest that they nonetheless capture an almost complete picture of the elasmofauna. The high number of species recorded is especially notable due to the mix of body size, trophic positions and ecological niches of the species represented, including benthic rays, apex sharks, small-bodied meso-predators and megaplanktivores. When separated by island (not including João Valente), Maio exhibited the highest relative abundance, followed by Sal and Boavista, which corresponds to the inverse gradient of the human population of the respective islands. We also found that more than 50% of all sharks for which size estimates were made were juveniles. Our findings highlight Cabo Verde's importance as an area for elasmobranch biodiversity in the Eastern Atlantic Ocean, as well as the need for the management and conservation of these species.

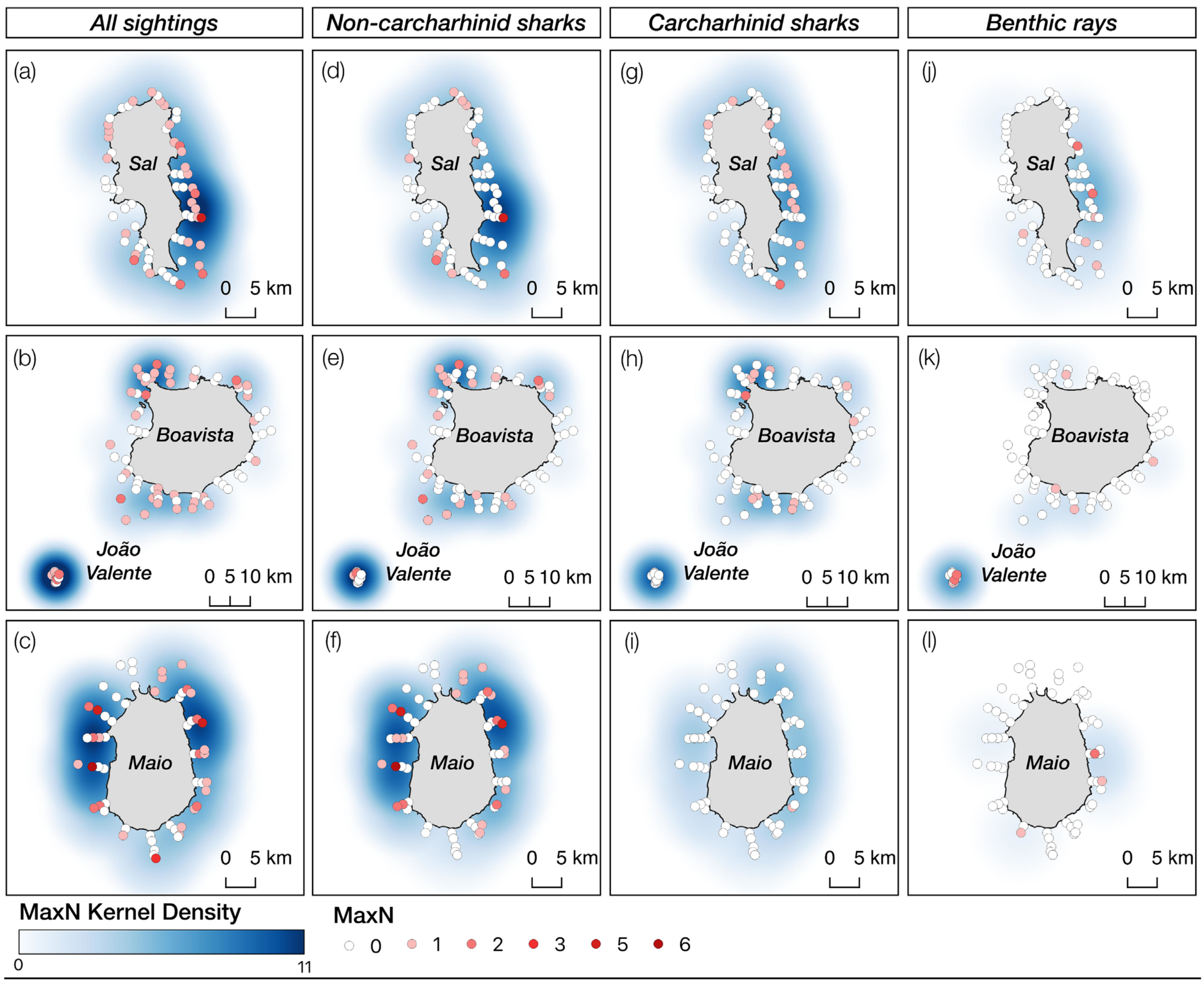

FIGURE 4 Distribution and abundance of elasmobranch sightings in BRUVs set in eastern Cabo Verde between 2015 and 2017. Dots indicate the location of each BRUV and MaxN for all elasmobranch sightings (a–c) and those belonging to three key functional groups: Non-Carcharhinids (d–f), Carcharhinids (g–i) and benthic stingrays (j-ls (j-l). Shading indicates the Kernel Density of MaxN across the surveyed islands, and the colours of dots are indicative of MaxN.

Overall, the small-bodied smoothhound (*M. mustelus*) was the most abundant species observed and was found to be relatively common on all three main islands, though it was not recorded at João Valente. *M. mustelus* is unique, being the only locally occurring species broadly targeted by artisanal fisheries, and its dried meat is consumed as 'cação'. Its exploitation is largely focused on the shallow coastal waters (<80 m deep), and although the species is not protected in Cabo Verde, there is a certain amount of ambiguity surrounding the sustainability and legality of the fishery. This is in part because 'cação' is a broad term that can also be applied to other small and juvenile sharks, including juvenile hammerheads, which are nationally protected (Resolução n° 56/2014).

The Atlantic weasel shark (*P. pectoralis*) is endemic to the ECA (Bates, 2009) and was one of the most abundant elasmobranch species in BRUV surveys at Cabo Verde. In Boavista and Maio, Atlantic weasel sharks accounted for 17% and 26% of species' frequency of occurrence, respectively; however, it was not recorded in Sal. While Maio and Boavista are connected by a shallower continental shelf, Sal is separated by a deep-water channel, which may limit the dispersal of some species. However, given the similarities in habitat composition, the proximity of Sal to northern Boavista and the widespread distribution of the Atlantic weasel shark in the ECA, the apparent absence of the species is perhaps unlikely to be explained by limitations in the species' range. Instead, this relative absence may be explained by the corresponding relative abundance of large-bodied predatory sharks, such as tiger sharks (*G. cuvier*), which are known to predate on smaller species of elasmobranchs (Dicken et al., 2017; Heithaus, 2001; Lowe et al., 1996; Simpfendorfer et al., 2001).

The apparent absence of mid-water species (namely Carcharhinid sharks) in Maio and João Valente, especially in relation to observations at Sal and Boavista, is noteworthy and may be indicative

TABLE 2 Results of GLMs showing models selected by AIC selection criteria. For each factor included in the model, the table reports the estimated effect size, its standard error (SE), the *z*-test statistic and the *P*-value associated with it (*P*). Bold numbers indicate significant factors (alpha < 0.05). Asterisks are indicative of a negative binomial GLM, otherwise, a Poisson error distribution was applied. Non-Carcharhinid sharks excluded nurse sharks. Latitude here is used as a proxy for distance from large human population centres, with northern latitudes being further away from cities. Only species groups and individual species with MaxN > 20 are included.

Non-Carcharhinid sharks	Estimate	SE	z	P	AIC	**A. weasel shark**	Estimate	SE	z	P	AIC
Intercept	35.98	10.29	3.50	**0.0005**	273.72	Intercept	−2.47	0.45	−5.52	**<0.0001**	161.05
Depth	−0.52	0.23	−2.29	**0.0219**		Depth	0.02	0.01	1.87	0.0610	
Unprotected	−0.45	0.30	−1.49	0.1351		**Nurse shark**					
Latitude	−2.33	0.66	−3.56	**0.0004**		Intercept	1.17	0.57	2.05	**0.0414**	141.75
Depth:Latitude	0.03	0.01	2.38	**0.0173**		Latitude	−0.06	0.04	−1.71	0.0878	
Carcharhinid sharks						Habitat Rock	−0.13	0.06	−2.11	**0.0364**	
Intercept	−19.02	5.11	−3.73	**0.0002**	215.46	Habitat Sand	−0.15	0.05	−3.00	**0.0030**	
Habitat Reef	−1.77	0.78	−2.25	**0.0242**		**Smoothhound**					
Habitat Rock	−0.59	0.68	−0.87	0.3849		Intercept	71.61	29.79	2.40	**0.0162**	146.37
Habitat Sand	−0.25	0.56	−0.45	0.6532		Depth	−1.30	0.57	−2.27	**0.0232**	
Unprotected	0.92	0.50	1.86	0.0628		Latitude	−4.93	1.94	−2.55	**0.0109**	
Latitude	1.05	0.31	3.34	**0.0008**		Depth:Latitude	0.09	0.04	2.38	**0.0171**	
Benthic rays						**Round fantail stingray***					
Intercept	−13.79	5.34	−2.58	**0.0098**	202.61	Intercept	−15.12	6.04	−2.50	**0.0123**	191.64
Habitat Reef	−3.16	1.11	−2.86	**0.0043**		Habitat Reef	−2.98	1.17	−2.56	**0.0105**	
Habitat Rock	−0.30	0.55	−0.54	0.5879		Habitat Rock	−0.06	0.66	−0.10	0.9229	
Habitat Sand	−0.96	0.54	−1.79	0.0740		Habitat Sand	−0.93	0.65	−1.43	0.1536	
Unprotected	1.07	0.56	1.92	0.0554		Unprotected	1.29	0.66	1.95	0.0516	
Latitude	0.73	0.33	2.24	**0.0254**		Latitude	0.79	0.37	2.14	**0.0327**	

of intensive fishing effort. João Valente has long been revered by fishers as having a high abundance of large-bodied sharks (ZLM pers. comm); However, no large-bodied Carcharhinid sharks were observed at this site during the course of this study. While the overall relative abundance of elasmobranchs for João Valente was indeed higher than any of the islands surveyed (RA = 1.20), this may have been influenced by the relatively small number of BRUVs set at this location in comparison to the other sites. Furthermore, despite the relatively high relative abundance of elasmobranchs at this site, sightings were dominated by nurse sharks (*G. cirratum*) and round stingrays (*Taeniura grabata*), with few other species recorded. João Valente is located on the route taken by artisanal fishers travelling between the main island of Santiago and productive fishing grounds in Boavista and Sal. Its remote location (30 nm from Boavista) ensures minimal enforcement of regulations, and consequently, João Valente is subjected to fishing activity from artisanal and semi-industrial boats, as well as foreign industrial fleets. Maio was also characterized by a higher encounter frequency of smaller-bodied and/or benthic elasmobranchs, and a scarcity of high-trophic-level species. In Sal, instead, Carcharhinid sharks constituted nearly 50% of the species encountered, and it was the only location where tiger sharks were sighted on BRUVs. The apparent latitude-related gradient in the relative abundance of Carcharhinid sharks, combined with the high relative abundance of mid-trophic-level demersal species, and the anecdotal knowledge of intense exploitation having occurred at both Maio and João Valente, suggest that large predators should be found at these sites and may have been removed by fishing pressure.

Some aspects of the survey design, such as seasonality and sampling habitat, could have the potential to confound the patterns observed, particularly affecting sightings of large-bodied carcharhinids. Though species accumulation curves suggested that the elasmofauna of the islands was exhaustively surveyed, fishermen and scientists working in the region report sightings of species that were not recorded by the BRUVs, especially among pelagic top-predators. Species commonly highlighted by fishers that did not appear on the analysed BRUV footage include the planktivorous whale shark (*Rhincodon typus*) and two species of hammerhead sharks, Scalloped and Smooth Hammerheads (*Sphyrna lewini* and *S. zygaena*). Analysis of species' occurrence on videos for this study was limited to the first 65 minutes after deployment of the video, as a means of standardizing results and for comparison to other BRUV studies (Phenix et al., 2019; Speed et al., 2019); However, many camera instalments remained in the water well past the 65-minute mark, and all videos were watched in their entirety. The two species of hammerhead sharks (*S. lewini* and *S. zygaena*) and a second dusky shark (*C. obscurus*) were observed on BRUVs after the 65-minute mark. Additionally, adult/sub-adult (2–2.5 m TL) hammerhead sharks (*Sphyrna* spp.) were observed at the surface in both Sal and Boavista

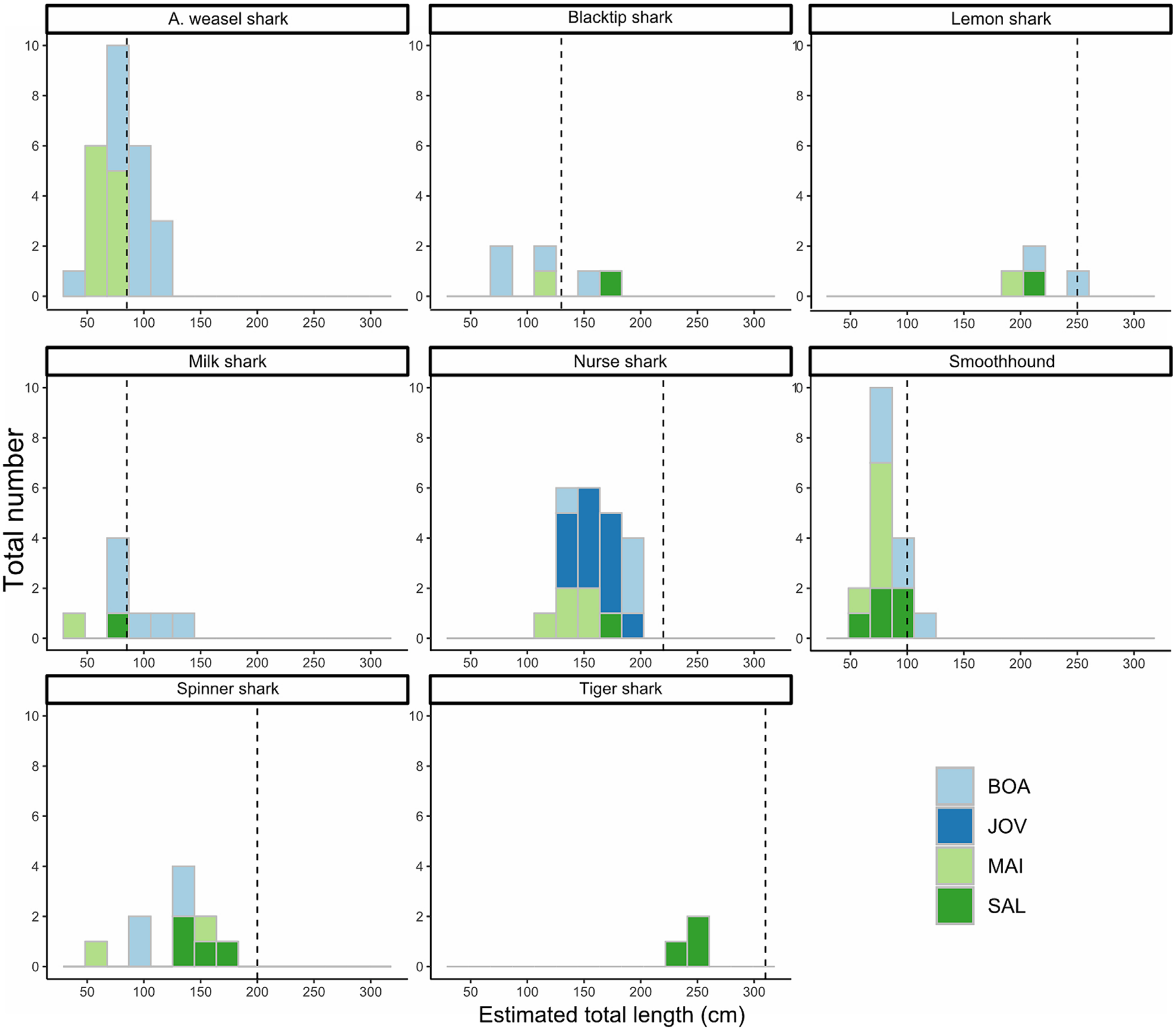

FIGURE 5 Length-frequency distribution of shark species for which sizes could be estimated from BRUVs in eastern Cabo Verde by island. Vertical dashed lines represent the approximate size at maturity for each species. BOA = Boavista, JOV = João Valente, MAI = Maio, SAL = Sal.

during the course of this study. It is likely that demersal BRUVs underestimated the species diversity of large-bodied sharks, especially of pelagic species. Pelagic and planktivorous sharks are less likely to appear on demersal cameras (REF), and their presence in coastal waters is strongly linked to seasonal behaviours such as foraging, parturition and/or environmental factors affected by depth and seasonality. Seasonal differences in species distributions may also affect the comparison of abundance for some groups, as many large Carcharhinid sharks are known to undertake large migrations (Chapman et al., 2015; Lea et al., 2015), and surveys were limited to discrete time periods. In 2015, surveys were conducted in April and May (Boavista) and in 2016 in May through July (Maio and Sal, respectively), while in 2017, the survey of João Valente was conducted at the end of September. However, many shark species are believed to be in greater abundance in Cabo Verde during the summer months (May–September; Z.L.M pers obsv) when water temperatures are higher, and prey species are seasonally abundant. This suggests that the differences in species composition between Sal, Maio and João Valente highlighted here likely hold true because all sites were surveyed during peak season. An expansion of surveys to cover other realms (e.g. pelagic BRUVs) as well as the adoption of other survey techniques (scientific longline) will likely provide a more complete picture of the species composition of the region.

In the last 25 years the islands of Sal and Boavista have seen significant development in response to growth in mass tourism, and Maio is slated for tourism expansion in the coming years. It is speculated that such rapid development in an insular environment may have a significant effect on local marine resources (Lima & Martins, 2010). Striking the right balance between increased tourism, natural resource use and the potential for economic alternatives for fishers will require careful consideration and cooperation among the private and public sectors. Marine Protected Areas (MPAs) can play an important role in safeguarding elasmobranch populations and fishery resources if properly designed and managed. In Boavista and Sal, existing MPAs introduced in 2003 (Decreto-Lei n° 3/2003 de 24 Fevereiro) currently afford limited protection to sharks and rays, as evidenced by the results of the GLMs, which indicated that protected areas had no positive impact on the relative abundance of elasmobranchs. The creation of these MPAs, in many cases, appeared to be an extension of terrestrial protected areas aimed primarily at other taxa (namely loggerhead nesting beaches and seabird colonies), and so may not always target key areas for elasmobranchs or be strengthened by clear regulations aimed at reducing anthropogenic pressures at sea. In Maio, following revisions of the MPA network conducted in 2014, two 'no-take' areas were introduced, and while it is too early to ascertain their effectiveness, their limited size is unlikely to have a significant impact on mobile species such as elasmobranchs (Conners et al., 2022; Halpern, 2003; Rhodes et al., 2019). As the government moves to strengthen the national network of MPAs, the results of these surveys suggest that particular attention should be given to the north-west of Boavista, the central-eastern coast of Sal and the west coast of Maio. It is also paramount that the enforcement of MPAs, which has so far been lacking in the country, be developed. In this regard, the involvement of artisanal fishermen and communities in the development and implementation of management and enforcement measures will prove paramount for the success of MPAs in Cabo Verde. Although efforts are underway to reinforce the national MPA network and adapt it to better target conservation goals for marine species, additional measures regulating the catch and trade of elasmobranchs in the country should also be developed. The implementation of Cabo Verde's National Plan of Action (NPOA) for sharks in conjunction with the implementation of enforced MPAs will be fundamental in conserving and sustainably managing elasmobranch populations while enhancing sustainable fisheries in Cabo Verde.

Overall, BRUVs represent an effective method for monitoring regional nearshore elasmobranch populations in Cabo Verde. The relatively low cost of the BRUV equipment required and the simplicity in its deployment coupled with its ease of replication gives great potential for expanding fisher engagement and baseline assessments to other islands, and the regular monitoring of future MPAs and critical habitats such as areas previously identified as nursery areas (Rosa et al., 2023; Seymour & Graham, 2016). While the use of BRUVs does have limitations, these can be alleviated if used in conjunction with other more traditional fishery-independent methods such as scientific longline, and newer methods such as eDNA, techniques that should be prioritized at sites like João Valente. As BRUV survey efforts are expanding in the country into areas not served by this study, collaboration amongst stakeholders and standardization of methods will also be paramount in obtaining a more complete assessment of the elasmofauna of the archipelago and detecting changes in abundance.

In conclusion, this study provides the first baseline of information for elasmobranch relative abundance in eastern Cabo Verde, showing the importance of this area for biodiversity in the region and the world while highlighting the potential ongoing deterioration of the national elasmofauna as a result of unregulated fishing. The high abundance of the endemic Atlantic weasel shark represented a bright spot in this study; as most shark populations in the region have been severely depleted (Diop & Dossa, 2011), Cabo Verde might represent a crucial hotspot of abundance for the conservation of this species. Future and ongoing studies will expand upon these data, as demersal BRUVs likely under-estimate the abundance and diversity of the elasmofauna of the area. Expanding surveys to the northern and southern islands of the archipelago, as well as surveying pelagic and deep-water ecosystems, is needed to catalogue the species that are increasingly subject to small-scale and industrial fishing mortality.

ACKNOWLEDGMENTS

We thank the Caboverdean government and the Direção Nacional de Ambiente (DNA) who authorized all scientific study (DNA, permits No. 10/2015, 03/2016 & 13/2017) and carried out in collaboration with traditional artisanal fishers. We gratefully acknowledge the support of The Ocean Foundation, the Mitchell-Peterson Family Foundation, the Wildlife Conservation Network, Houston Zoo, Anthony Nolan and Monaco Explorations, as well as the crew aboard the Yersin, for making this study possible. We recognize traditional fishers Angelito Monteiro, Carlos Gomes and João Lima for their tireless work surveying. We thank Thomas Meyer, Cynthia Xiu and Amanda Resterer for their contribution in reviewing BRUV footage.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to disclose.

DATA AVAILABILITY STATEMENT

All data used in the manuscript are available as supplementary files to this publication (BRUV_Effort.csv and BRUV_SIghtings.csv).

ETHICS AND PERMIT APPROVAL STATEMENT

The research presented in this study was conducted under approval from Direcção Nacional do Ambiente (DNA) of Cabo Verde under permits No. 10/2015, 03/2016, 13/2017.

PERMISSION TO REPRODUCE MATERIALS FROM OTHER SOURCES

No materials from other sources have been reproduced in the work.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Seymour, Z.T.A., Monteiro, Z.L., Monteiro, A., Baremore, I.E., Garzon, F. & Graham, R.T. (2024). Baseline assessment of the coastal elasmobranch fauna of Eastern Cabo Verde, West Africa. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 34(9), e4206. https://doi.org/10.1002/aqc.4206