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Artisanal fisheries catch highlights hotspot for threatened sharks and rays in the Republic of the Congo

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Abstract

Global catch rates of sharks and rays from artisanal fisheries are underreported, leading to a lack of data on population status. This forms a major barrier to developing effective management plans, such is the case in Central and West Africa. Over 3 years, we undertook the first systematic quantitative assessment of sharks and rays landed by an artisanal fishery in the Republic of the Congo. During 507 sampling days (mean 14 surveys per month), we recorded 73,268 individuals. These comprised 42 species, of which 81% are considered at an elevated risk of extinction. Landings were dominated by immature individuals, especially for species of conservation concern. Presence of species thought to have largely disappeared from the region such as the African wedgefish (*Rhynchobatus luebberti*) and smoothback angelshark (*Squatina oculata*) suggest Congolese waters are a potential stronghold for these species—warranting increased protection. We identified seasonality of catch within years, but not across years. Both inter- and intra-annual trends varied by species, signifying annual fluctuations in catch of each species but consistent catch of all species year-on-year. Analysis showed increased catch between the short-wet and the long-wet, and the long-dry seasons (January–February and August–September). Lowest catch was shown to occur during the short-wet and the short-dry seasons (October–December), which may provide an opportunity for seasonal closures or gear restrictions.

KEYWORDS

Africa, Atlantic Ocean, bycatch, conservation, elasmobranch, management, small-scale fishery

1 | INTRODUCTION

Globally, there is growing concern regarding population declines of chondrichthyan fishes (sharks, rays, and chimaeras, herein "sharks and rays"). These declines are primarily caused by overexploitation from direct and indirect fishing activities (Baum et al., 2003; Dulvy et al., 2021; Pacoureau et al., 2021). Reported global shark and ray catch has declined by approximately 20% since 2003 (Davidson et al., 2016), with an estimated 70% decrease in abundance of oceanic sharks and rays since 1970 (Pacoureau et al., 2021). This has resulted in over one-third of shark and ray species being threatened and having an elevated risk of extinction (Dulvy et al., 2021). Shark and ray life-history traits, characterized by slow growth, late sexual maturity, low fecundity, and extended life spans make them more susceptible to exploitation than faster growing teleosts (Hutchings et al., 2012; Myers et al., 2007). Furthermore, per capita population growth and thus rebound potential have been shown to be considerably lower than those of teleosts (Hutchings et al., 2012). This presents challenges to fisheries management and conservation. Assessments of extinction risk revealed that within sharks and rays, sawfish, wedgefish, and guitarfish are amongst the most imperiled families globally (Dulvy et al., 2016; Jabado, 2018; Kyne et al., 2020; Moore, 2017). International trade of the fins of these species has incentivized the targeting and retention of sharks and rays (Dent & Clarke, 2015).

The global artisanal fisheries sector has shown a higher rate of motorization compared to the industrial sector. Cumulative engine power is now comparable between the two (ca. 73 gigawatts; Rousseau et al., 2019). The artisanal fishery sector currently represents a substantial proportion of the global fishing effort, employing approximately 12 million fishers globally and plays a key role in many local and national economies. These fisheries contribute to food security, employment, and poverty prevention (Belhabib et al., 2015; Palomares & Pauly, 2019). Nonetheless, despite their size, important contribution, and increasing fishing power, the impact of small-scale fisheries on sharks and rays remains poorly understood (Diop & Dossa, 2011; Moore et al., 2019). Most reported estimates of shark and ray catch are based on industrial fleets and mostly consider total weight, not number of individuals (Davidson et al., 2016). However, considering the high number of juveniles landed in artisanal fisheries globally (Appleyard et al., 2018; Hacohen-Domené et al., 2020; Kiilu et al., 2019), the scale of shark and ray fishing by small-scale fleets is likely to be several orders of magnitude higher than currently estimated (Cashion et al., 2019; Pauly & Zeller, 2016).

The Gulf of Guinea is a marine biodiversity hotspot (Polidoro et al., 2017). Yet, systematic assessments of landing sites as well as satellite tracking data describing the spatial ecology of sharks and rays in this region are largely lacking (Diop & Dossa, 2011; Renshaw et al., 2023). Consequently, several countries within the Gulf of Guinea have been identified as those where governance and capacity need strengthening. This is to align national legislation with commitments under global initiatives for shark and ray conservation and management (Vasconcellos et al., 2018). Such is the case in the Republic of the Congo, where a major barrier to designing effective conservation and fisheries management plans stems from a lack of baseline information. The shortage of accurate catch records (both in terms of species identification and quantities landed) alongside insufficient information on populations and seasonality of occurrence all contribute to the lack of a formal plan of action for sharks and rays. These are exacerbated by a lack of knowledge on the impact of fisheries and the challenges in monitoring illegal, unreported, and unregulated (IUU) fishing activity that can lead to conflict (Doherty et al., 2021). Detailed data on species composition, population trends, and threats are required to help drive changes in national and regional policy, as well as facilitate targeted management decisions.

2 | METHODS

2.1 | Study area and policy context

The Republic of the Congo is located on the Atlantic coast of Central Africa (Figure 1). The exclusive economic zone (EEZ) is situated in the highly dynamic, biodiversity-rich transition zone between the Guinea Current and Benguela Current Large Marine Ecosystems. Fishing occurs throughout the year by both industrial and artisanal fishing vessels (herein referred to as "pirogues") with both sectors primarily operating across similar areas along the continental shelf (Doherty et al., 2021; Metcalfe et al., 2017; Momballa, 2020). Two fishing zones are designated within the Republic of the Congo's EEZ. An artisanal zone reserved exclusively for artisanal fishing activities (approximately 5% of EEZ) and an industrial zone (approximately 93% of EEZ) within which industrial fishing vessels either registered in the Republic of the Congo or from a State who the Republic of the Congo has an agreement can operate legally (Doherty et al., 2021). The final 2% of the EEZ is within a national park (Parc National Conkouati-Douli), within which there is an eco-development zone that small-scale fishers who are resident in the park can operate. Sharks and rays are regularly targeted, or incidentally captured (but retained) by industrial and small-scale fishers in this

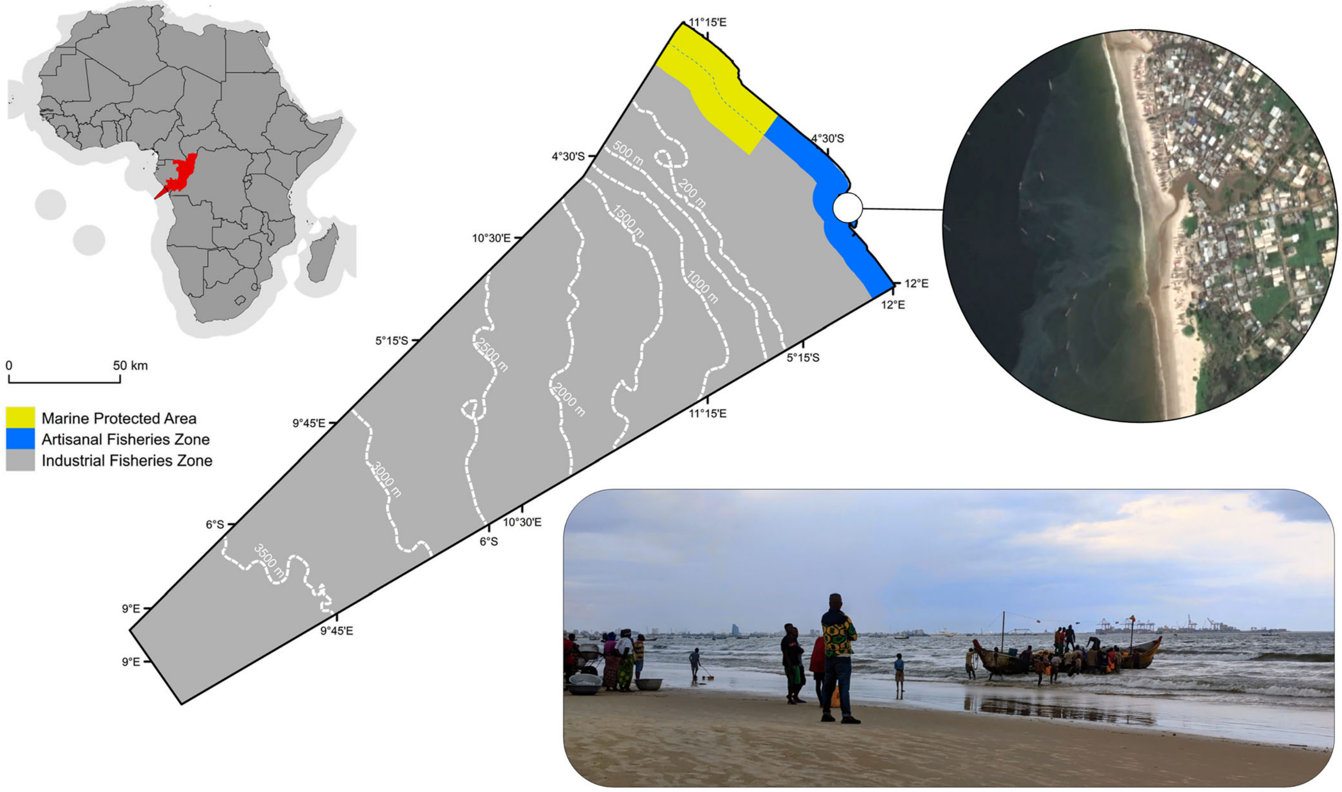

FIGURE 1 Context of the Republic of the Congo's EEZ within the continent of Africa, designations of artisanal (blue polygon) and industrial (gray polygon) fishing zones, and Conkouati-Douli National Park MPA (yellow polygon). Bathymetric depth contours shown (source: GEBCO). Major landing site of Songolo shown in circular insert (Source: Google Earth), and a picture of a typical scene of boats arriving at Songolo to land their catch.

region. In 2001, the Ministry of Forest Economy in charge of Fisheries Resources (*Ministère de l'Economie Forestière chargé des Resources Halieutiques; MEFRH*) issued a ban on shark and ray fishing to protect them from overexploitation. After 14 months, this ban was lifted to enable the Ministry of Fisheries to produce an inventory that would inform the development of a national plan of action on sharks. However, due to a lack of resources, both in terms of formal experience in fisheries assessments, and funding, no official catch statistics were collected. This left shark and ray fishing to continue unmonitored.

2.2 | Landing surveys

In 2018, the Directorate of Fisheries and Aquaculture for Pointe Noire and Kouilou (DDPAPN/K) requested support to address this knowledge gap in shark and ray catch and enhance institutional capacity and awareness. This led to the implementation of bespoke training by the authors (Philip D. Doherty, Godefroy De Bruyne, Kristian Metcalfe) in conducting landing surveys at the Pointe Noire Artisanal Fishery Support Centre (Centre d'appui à la pêche artisanale; CAPAP) in Songolo (4° 44′47 S, 11° 50′58 E). This is a thriving fisheries landing and processing site, the largest in the country hosting an estimated 400 pirogues (>60% of the artisanal fleet). This is a mixed gear fishery deploying surface drifting gillnets, gillnets targeting sharks and rays (large mesh size; surface and demersal), seine nets, bottom set longlines, and handlines (Table S1). Songolo was selected as the focal study site as it hosts the majority of fishing vessels, is an important market to local communities, and there was established collaborations and trust with fishers—a critical factor in enabling robust data collection.

Landing site survey data were collected for 3 years commencing January 2019. Surveys were conducted by two trained Congolese observers (authors Emmanuel Dilambaka and Baudelaire Dissondet Moundzoho) visiting Songolo 4 days per week where possible. Given the dynamic and often frenetic nature of landings within artisanal fisheries (where vessels sometimes unload catch into smaller pirogues to bring to shore), surveys were conducted on pirogues landing in front of the trading market. This enabled catch data to be assigned to the

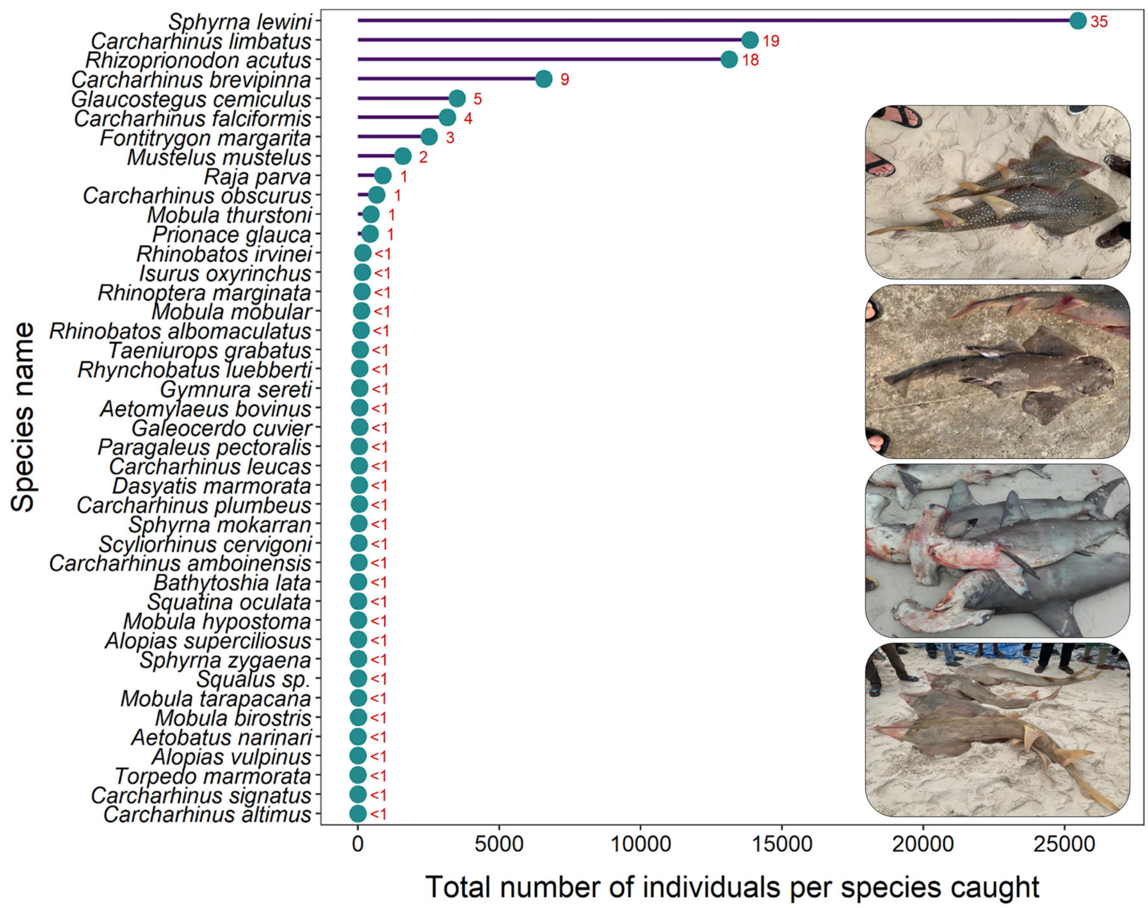

FIGURE 2 Total number of individuals landed at Songolo, the Republic of the Congo for each species recorded ($n = 42$). Bars and filled circles represent the total number of individuals, displayed numbers represents the percentage contribution of that species to the total catch. Inset pictures show examples of Critically Endangered sharks and rays observed during landing surveys (top to bottom) African wedgefish (*Rhinobatos luebberti*), smoothback angelshark (*Squatina oculata*), scalloped hammerhead (*Sphyrna lewini*) and blackchin guitarfish (*Glaucostegus cemiculus*).

correct vessel based on their unique identification number. Individual pirogues arriving at the landing site were randomly selected on the beach to facilitate observing whole landed sharks before processing began. All sharks and rays landed (Figure 2) were identified to species level (Campagno, 1984; Ebert et al., 2014; Edwards et al., 2001; Last et al., 2016; Seret, 2006; Stevens et al., 2018), number of individuals counted, and the total weight per species recorded. As part of our activities, we worked closely with fishers to develop the survey protocol to minimize disturbance to normal fishing and trading operations at Songolo. Therefore, weights were recorded by combining weights of boxes of individuals organized by species. However, for larger individuals, weights were recorded using a suspended weighing scale. Observers also collected photographs for species identification confirmation and future records. As is characteristic of small-scale fisheries across Central Africa, fishers often deploy nets comprised of multiple panels that have different dimensions and mesh size, as well as secondary gears such as handlines during fishing trips that last several days. Consequently, it was not possible to reliably assign catch associated with each trip to individual gear types and reliably generate estimates for Catch Per Unit Effort (Table S1).

2.3 | Data processing and analysis

To assess the maturity of sharks and rays landed at Songolo, we rearranged the length–weight relationship equation ($W = aL^b$ to $L = (W/a)^{1/b}$) to estimate the length of individuals caught. Where $W =$ weight (g), $L =$ length (cm), $a =$ intercept value from length–weight regression, and $b =$ slope value from length–weight regression. Values of a and b were obtained from FishBase (Froese & Pauly, 2019) using the *R* package *rfishbase* (Boettiger et al., 2012) and lengths at maturity obtained from the

IUCN Redlist (IUCN, 2022). Values of a and b were averaged (mean) across multiple records from linear regressions within the FishBase repository and used to estimate nominal weight per individual from landings data (total weight/number of individuals). We then applied these estimates as values of W in the rearranged length–weight equation to approximate mean lengths of individuals from the most frequently observed species ($n = 6$ contributing at least 5% of the total catch by number of individuals observed).

To determine the effectiveness of landing surveys, species accumulation curves were generated for increasing sampling effort (landing site visits). We used the *iNEXT* package (Hsieh et al., 2020) to calculate rarefaction curves based on species presence/absence, and predict new species detection with further increasing of sampling effort along with the associated bootstrapped 95% confidence intervals (Chao et al., 2014).

Finally, we investigated seasonality, both within years (intra-annual) and between years (inter-annual) of catch of the top 12 shark and ray species (contributing at least 1% of total catch by number of individuals). As we wanted to know how relationships varied between groups (species) as well as if the relationship holds across groups (all species considered together), we used a hierarchical general additive model approach (HGAM; Pedersen et al., 2019). We fitted a negative binomial HGAM (to account for overdispesion) including fixed effects of species, fitted as a categorical effect, month within year ($n = 12$) and months between years ($n = 36$) fitted as a cubic regression splines, and month within year and months between years fitted as variable smooths by species. Models were fitted using the *mgcv* package (Wood, 2017) and ranked by Akaike's Information Criteria (AIC) using subset selection of the maximal model via the *MuMIn* package (Barton, 2018). A top ranked model was defined as the model where ΔAIC $\leq$6 units of the best supported model (Harrison et al., 2018) after exclusion where a simpler model attained stronger weighting (Richards et al., 2011). All data analysis and visualization were conducted in *R* v 4.0.2 (R Core Team, 2020) using packages *dplyr* (Wickham & Francois, 2020) and *ggplot2* (Wickham, 2016).

3 | RESULTS

3.1 | Landing survey effort

Between January 8, 2019 and December 24, 2021, landing surveys were conducted on 507 separate days (46% of days within 3 years). Sampling effort was consistent across years, with an average of 16 ± 2 days per month (range: 11–19 days) in 2019, 15 ± 2 days per month (range: 10–18 days) in 2020, and 15 ± 2 days per month (range: 11–17 days; Table S2) in 2021. Data from 304 different pirogues was collected (~76% of the pirogues within the fleet) who fished for an average of 4 ± 2 days per trip (range: 1–10 days) in 2019, 5 ± 1 (range: 1–11) in 2020, and 6 ± 2 (range: 1–11) in 2021 (Table S2).

3.2 | Species composition

Across the 507 sampling days, a total of 73,268 individuals (2019; $n = 29{,}951$, 2020; $n = 23{,}620$, 2021; $n = 19{,}697$) were recorded (Tables S3 and S4; Figure 2), consisting of 42 species, weighing a total of 527,217 kg (~527 tonnes; Table S4; Figure S1). Of these 42 species, 9 (21%) are classified as Critically Endangered by the International Union for Conservation of Nature (IUCN), 13 as Endangered (31%), 12 as Vulnerable (29%), 6 as Near Threatened (14%), and 2 as Data Deficient (5%; Figure S2). These findings indicated that 81% of all species recorded (98% of total catch by number of individuals) are considered at an elevated risk of extinction. The family *Carcharhinidae* dominated landings by number of individuals (52% of total catch), followed by *Sphyrnidae* (35%) and *Glaucostegidae* (5%). These families contain Critically Endangered species listed in Appendix II of CITES (scalloped hammerhead; *Sphyrna lewini* = 35% of total catch by number of individuals, and blackchin guitarfish; *Glaucostegus cemiculus* = 5% of total; Figure 2), with many of these species of conservation concern landed year-round in large numbers (Figure 2 and Figure S1).

Landings by weight were dominated by individuals from the *Carcharhinidae* family (66% of total) followed by the *Sphyrnidae* (23%), *Mobulidae* (4%), and *Glaucostegidae* (3%) familes. These families contain Critically Endangered and Endangered species listed in Appendix II of CITES (scalloped hammerhead = 23% of total catch by weight, dusky shark; *Carcharhinus obscurus* = 4%, blackchin guitarfish = 3%, and bentfin devilray; *Mobula thurstoni* = 3%; Figure S1).

There were notable presences of Endangered and Critically Endangered species observed at Songolo, including 17 records of smoothback angelsharks (*Squatina oculata*), 33 great hammerhead sharks (*Sphyrna mokarran*), 57 African wedgefish (*Rhynchobatus luebberti*), 102 white-spotted guitarfish (*Rhinobatos albomaculatus*), 165 spineback guitarfish (*Rhinobatos irvinei*), 660 dusky sharks, 147 shortfin mako sharks (*Isurus oxyrinchus*), and five species from the *Mobulidae* family (giant devilray; *Mobula mobula*; $n = 121$, Atlantic

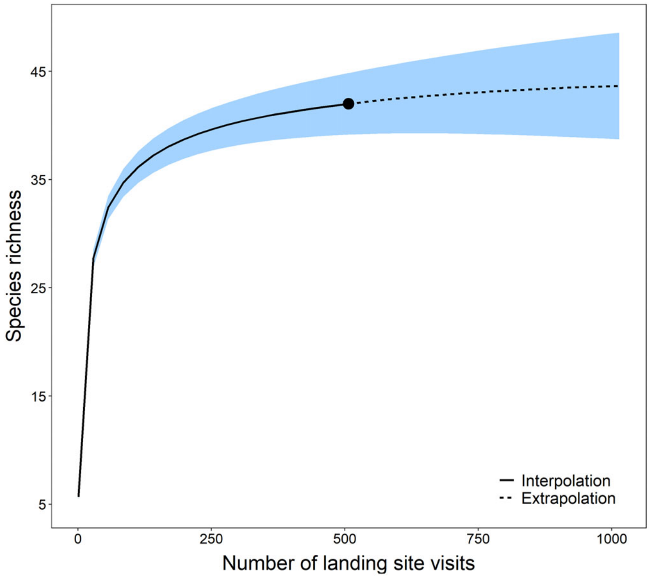

FIGURE 3 Species accumulation curve for increasing number of landing survey visits. Black circle denotes observed species richness during landing surveys ($n = 42$ species; 507 landing site visits), solid black line denotes interpolated number of observed species to double the effort conducted ($n = 1014$ landing site visits), and dashed black line denotes extrapolated number of species likely to be observed with increasing landing site visits. Blue shaded area denotes 95% confidence intervals.

devilray; *Mobula hypostoma*; $n = 15$, sicklefin devilray; *Mobula tarapacana*; $n = 6$, bentfin devilray; $n = 451$, and giant manta ray; *Mobula birostris*; $n = 5$).

Species rarefaction curves showed rapid accumulation of observed species from landing surveys, beginning to plataeu at approximately 250 landing site visits (Figure 3). This is a result of fewer new species being observed as survey number increase suggesting reaching the maximum number of species observable. The extrapolated prediction of new species detection with further increasing of sampling effort showed that a doubling of survey effort ($n = 1014$ survey days) would likely yield only a 5% increase in observed species from 42 to 44 (Figure 3).

3.3 | Intra- and inter-annual seasonality

Results from HGAMs showed intra-annual (within year) variation occurred at Songolo, showing annual seasonal variance in catch of sharks and rays. Effects from the model show overall catch of individual sharks and rays was higher in the transition between the short-wet and long-wet seasons (January–February) and toward the end of the long-dry season (August–September). Effects from the model shows the lowest level of shark and ray catch to occur through the short-wet and begininng of the short-dry seasons (October–December; Figure 4; Table S5). There was no evidence of an overall trend in inter-annual (between years) variance, indicating consistency in shark and ray catch year-on-year. However, catch appeared to decline in the final six-months of this study perod (April–December 2021; Figure 5; Table S5).

There was no effect of species as a driver of catch of sharks and rays independently; however, when interacting with temporal scales, intra- and inter-annual trends were apparent (Figures 4 and 5; Table S5). For instance, effects from the model show intra-annual catch of scalloped hammerhead sharks, blacktip sharks (*Carcharhinus limbatus*), and bentfin devilrays to be lower between February and July (long-wet to toward the end of long-dry seasons) and much higher from August to December (end of long-dry, through short-wet, and into short-dry seasons). Catch of spinner sharks (*Carcharhinus brevipinna*) appear higher early in the year (short-dry and long-wet seasons), and decreased between June and August (long-dry season). African brown skate (*Raja parva*) and blue sharks (*Prionace glauca*) trends showed distinct peaks in catch during the middle of the year (May–September; long-dry season). Common smoothhound (*Mustelus mustelus*) and dusky sharks trends showed high variabliity in catch throughout the year, with milk shark (*Rhizoprionodon acutus*), blackchin guitarfish, silky shark (*Carcharhinus falciformis*), and daisy stingray (*Fontitrygon margarita*) catch remaining consistent throughout the year (Figure 4; Table S5).

Inter-annual catch of scalloped hammerhead sharks reflected the intra-annual seasonality observed, with these trends remaining consistent across the study period (Figure 5; Table S5). Blacktip sharks showed some evidence of intra-annual variation across years, with a large decline in catch from November 2020, recovering in July 2021. Milk sharks showed large inter-annual variation with increased catch trends in late 2019 until early 2021, then declining for the rest of the study period. Spinner sharks, dusky sharks, and blackchin guitarfish trends all showed high levels of catch in early 2019, declining through to 2021, where catch began to increase again. Silky sharks had relatively consistent catch, with intra-annual seasonal fluctuations, apart from a decline during mid-2020. There were increased effects from the model of bentfin devilrays from late 2019 until mid-2020, otherwise remained relatively consistent. For blue sharks, there was inter-annual variability in catch, where effects increased through 2019, peaking in early 2020, then declining until late 2021 where effects from the model appear to increase. Trends of daisy stingray, common smoothhound, and African brown skate catch remained consistent throughout the study period (Figure 5; Table S5).

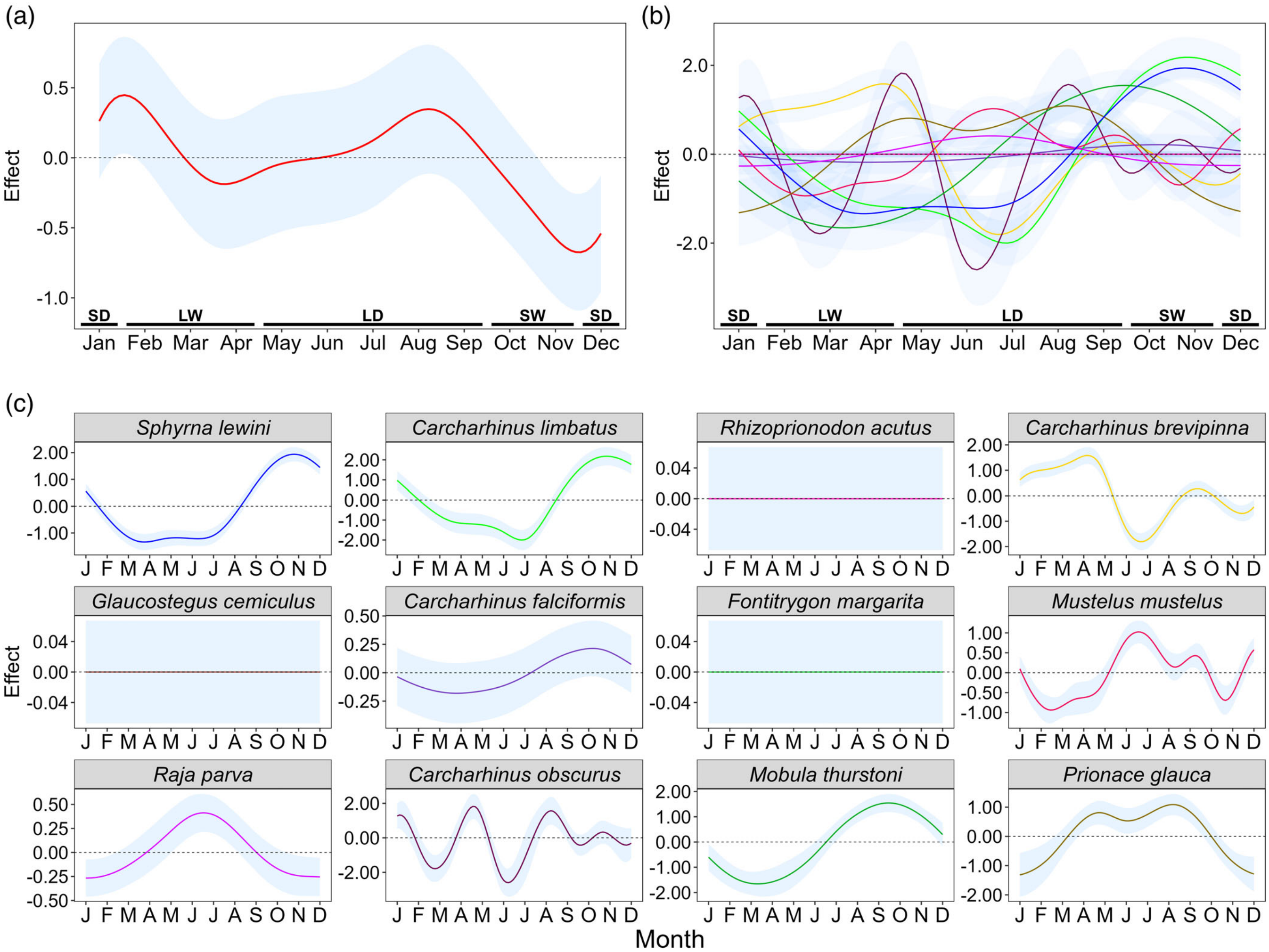

FIGURE 4 Intra-annual seasonality of catch of the top 12 most frequently caught species of sharks and rays at Songolo. (a) Overall relationship of catch levels within a year across groups of species, (b) response curves for each individual species, and (c) individual smooths for each species plotted in order of frequency of catch. Solid lines denote estimates of the smooth term from a hierarchical general additive model (HGAM), shaded areas denote the 95% confidence intervals. Seasons are denoted by labeled solid black lines (SD = short dry; LW = long wet; LD = long dry; SW = short wet).

3.4 | Maturity

Estimated lengths of individuals for the six most frequently occurring species showed a high proportion of immature individuals being landed (Figure 6). Estimates for milk sharks show a narrow range of lengths landed, largely of mature individuals. Spinner sharks showed a bimodal range of lengths landed, with the estimated mean length close to length at maturity for this species (Figure 6). For the other species for which lengths were estimated (silky, scalloped hammerhead, blacktip sharks, and blackchin guitarfish), the vast majority of individuals landed were estimated to be of sizes deemed immature, with mean estimate lengths well below lengths at maturity for these species (IUCN, 2022; Figure 6). All of these species are landed in large quantities, and classified as Critically Endangered.

4 | DISCUSSION

Our study vastly improves current knowledge regarding species richness and relative occurrence of shark and ray species exploited in Congolese waters. Landing site surveys documented a high proportion of threatened species, caught in large quantities, and across multiple years. There were occurrences of species such as African wedgefish and smoothback angelshark, thought to have largely disappeared from the region. This shows that the areas exploited by small-scale fishers (shallow coastal waters; Metcalfe et al., 2017) may represent a stronghold and/or

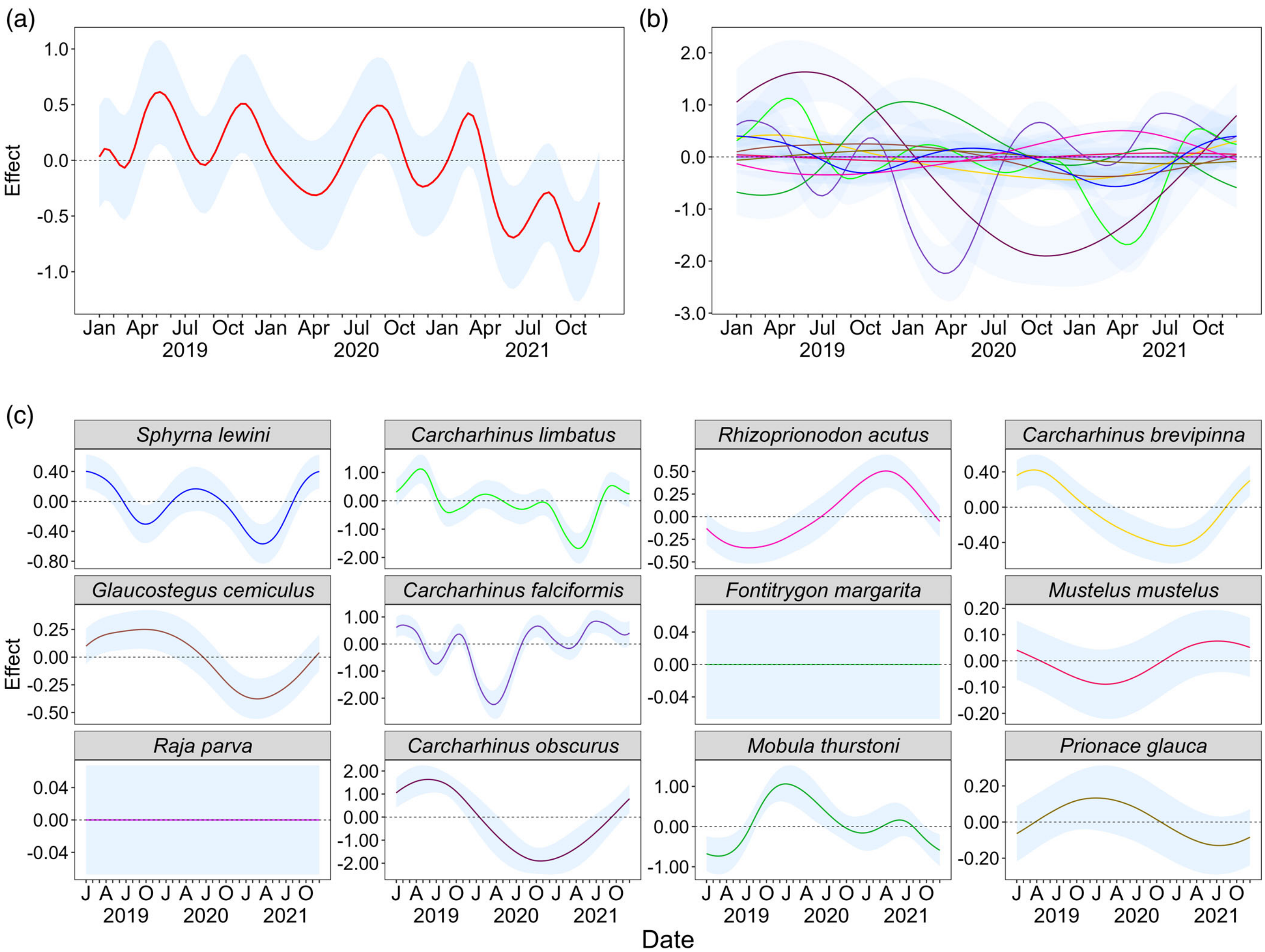

FIGURE 5 Inter-annual seasonality of catch of the top 12 most frequently caught species of sharks and rays at Songolo. (a) Overall relationship of catch levels between years across groups of species, (b) response curves for each individual species, and (c) individual smooths for each species plotted in order of frequency of catch. Solid lines denote estimates of the smooth term from a hierarchical general additive model (HGAM), shaded areas denote the 95% confidence intervals.

range expansion for several focal species of global conservation and monitoring efforts. These findings, based on observations from systematic surveys, are pertinent given the need to identify locations where area-based conservation can be applied for sharks and rays. This is particularly the case given these findings match many of the criteria set out to classify Important Shark and Ray Areas (ISRAs; Hyde et al., 2022). Most notably criterion A–C; vulnerability, range restriction, and life-history where areas are important to persistence and recovery of threatened sharks and rays, areas hold regular or predictable presence of range-restricted sharks and rays, or areas are important to sharks and rays for carrying out vital functions across their life-cycle (Hyde et al., 2022).

We show intra-annual seasonality at Songolo, but no effect of inter-annual temporal scales on shark and ray catch. This suggests that whilst catch varies within a year, shark and ray catch are comparable and consistent year-on-year. We observed an interaction effect between species and intra- and inter-annual temporal scales. There was variation amongst species both with an annual cycle but also across the entire study period. Most notably, fewer individuals of scalloped hammerhead and blacktip sharks (the top two most caught species) were landed at the beginning of the year during the long-wet and long-dry seasons, but increased catch occurred as the long-dry season moved into the short-wet season. There were several species that showed seasonality on multi-year scales. Milk sharks had decreased catch during 2019 and early 2020, but much higher numbers throughout the rest of 2020, declining again from early 2021. Catch of the Endangered dusky shark were higher during early 2019, declining through 2020, beginning to increase again throughout 2021. These multi-year fluctuations may be a

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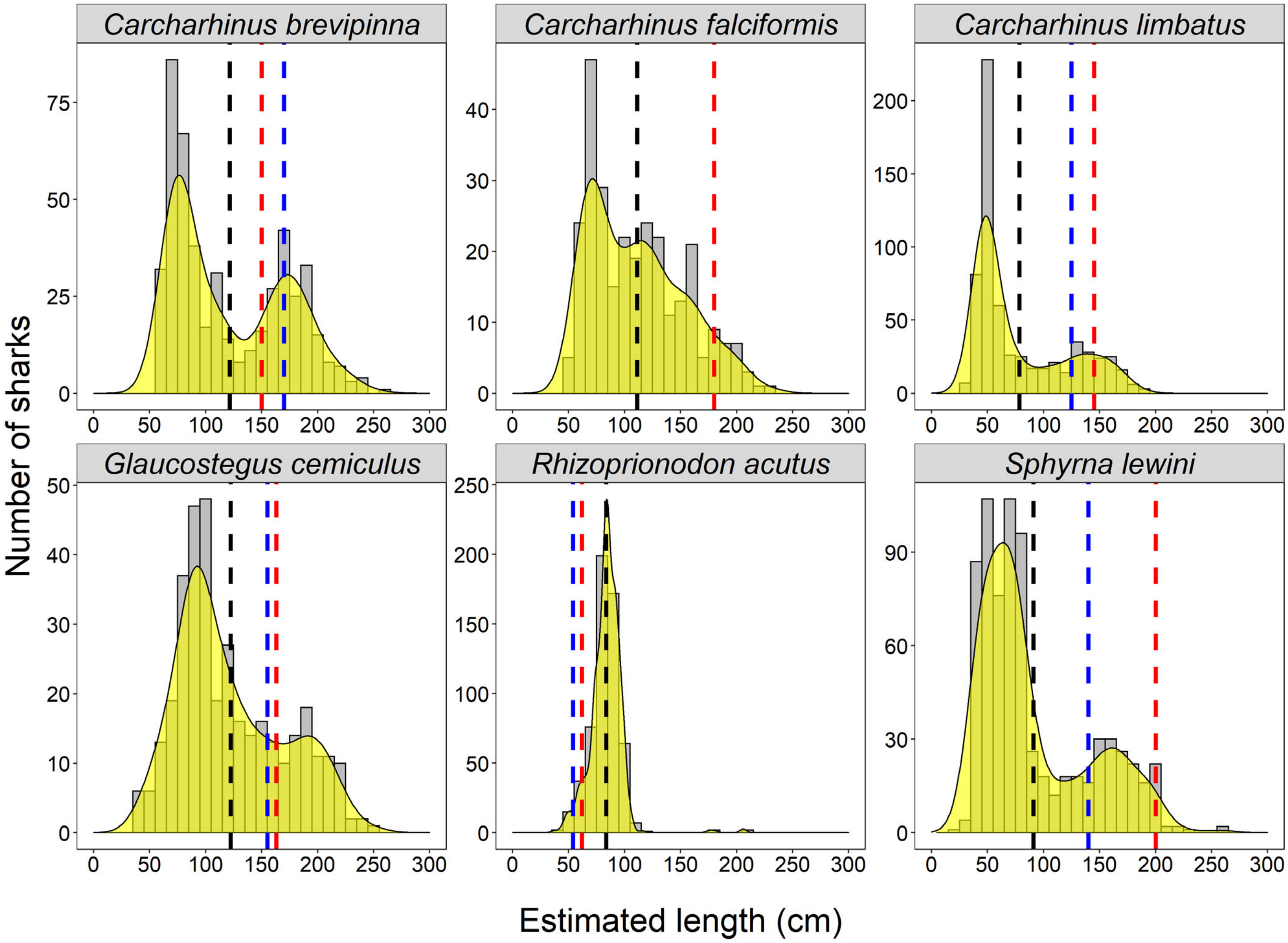

FIGURE 6 Histogram (gray bars) and density (yellow polygon) of estimated lengths for the top six most frequently landed species during landing site surveys (spinner shark; *Carcharhinus brevipinna*, silky shark; *Carcharhinus falciformis,* blacktip shark; *Carcharhinus limbatus,* blackchin guitarfish; *Glaucostegus cemiculus,* milk shark; *Rhizoprionodon acutus*, and scalloped hammerhead; *Sphyrna lewini*). Black dotted lines denote mean estimated length of landed individuals, red dotted lines denote length at maturity for females, and blue dotted lines denote length at maturity for males (IUCN, 2022).

product of these species' life-history characteristics. Dusky sharks are known to exhibit broad-scale movements and favor continental shelf waters (Hoffmayer et al., 2010). Reproduction in dusky sharks is not well understood; however, it is likely this species carries out at least a 1-year resting period folowing parturition and has a gestation period of up to 2 years (Branstetter & Burgess, 1996; Romine et al., 2009). These factors may result in longer absences from the region that are not symptomatic of population decline. Thus, there is an urgent need for long-term, multi-year landing surveys and spatial occupancy information (e.g., from satellite telemetry studies) to investigate this further. This will help establish if time closures or gear restrictions could allow stocks of particularly exploited species to recover, and when and where fisheries and sharks are more likely to overlap.

Regular and systematic surveys of landing sites can obtain detailed information on species landed within a fishery where methods and fishing grounds remain relatively constant. We show that in a moderately short period of intensive survey effort, much of the species richness within this artisanal fishery can be observed (95% of species observed in 3 years obtained after 281 days: 55% of effort). This should therefore provide sufficient information to establish key species groups from which to create management strategies from.

Globally, artisanal fisheries that land sharks are often largely comprised of immature individuals; for example, Pacific Ocean (Avalos Castillo & Santana Morales, 2021), Atlantic Ocean (Hacohen-Domené et al., 2020; Seidu et al., 2022), and Indian Ocean (Haque et al., 2021; Kiilu et al., 2019). Our study also revealed a high prevalence of immature individuals of the most commonly landed species, which may be indicative of important nursery habitat or pupping grounds for species of conservation concern (Heupel et al., 2007). This is particularly likely for blackchin guitarfish and scalloped hammerhead sharks. This is evidenced by the latter comprising the most individuals in the fishery, but very similar composition by weight as spinner and blacktip sharks. This is further substantiated by direct observations of fresh, unhealed umbilical cord scars on landed individual sharks (Figure S3) and reports from fishers of individual sharks and rays pupping upon being landed. Data on the spatial distribution of artisanal (Metcalfe et al., 2017) and industrial fishing activity (Doherty et al., 2021) shows fishing effort is highly concentrated in continental shelf waters (<200 m depth). This means there is a high level of overlap of fishing activity and coastal species. This therefore increases pressure at vulnerable times such as when species use these areas as parturition or nursery grounds. This high level of pressure is likely a product of: (a) a lack of teleost fish due to prolonged exploitation and active industrial fisheries, including distant water fleets and IUU activity (Doherty et al., 2021; Sumaila et al., 2020) and (b) the role sharks and rays in local food security. Sharks and rays are a cheap source of protein, which also provide an extra source of income from selling sought after fins (Diop & Dossa, 2011; Sall et al., 2021). There are no historic data on species landed in the Republic of the Congo, but a recent report showed ~70% of interviewed fishers felt shark populations in Congolese waters has remained stable over time (Momballa, 2020). However, this does not address specific species, and therefore abundance may have remained constant, but composition may have changed over time. This is evident from our results showing variation in species-specific abundance across the 3 years of data but consistent catch year-on-year. Changes in species composition or size of fished sharks and rays could have serious implications for the sustainability of a fishery (Stevens, 2000), where even a slight increase in juvenile mortality can greatly impair the sustainability of coastal shark and ray fisheries (Cortés, 2002).

When we consider the findings of this study in a global context, the number of sharks and rays landed is exceptionally high ($n = 73{,}268$; mean = 24,423 per year). For example, ~12,500 individual sharks and rays were observed from 205 landing site visits from United Arab Emirates Gulf waters (Jabado et al., 2015). A similar study, spanning 12 months assessing shark and ray catch at multiple landing sites along the Kenyan coastline observed only 1610 individuals sharks and rays landed by a fleet that consists of approximately 3100 artisanal vessels (Kiilu et al., 2019). The most recent estimate of marine megafauna catch in small-scale fisheries in the southwestern Indian Ocean from 21 landing sites across three countries estimated an annual catch of between 2.2 and 2.7 million individuals (Temple et al., 2019). This latter analysis was based on more complete data on gear type, and fishing effort associated to catch than was available for this study. Furthermore, whilst Songolo is the largest artisanal fisheries landing site, there are a further 28 sites across the Republic of the Congo (hosting >30% of the artisanal fleet). As such, the magnitude of shark and ray catch is likely to be much greater given similar preferences in spatial patterns of resource use (Metcalfe et al., 2017).

Generally, current approaches to shark management employ one of the following strategies: Target-based approaches maximizing sustainable exploitation, limit-based strategies banning fisheries exploitation regardless of sustainability or status of species-specific stock (e.g., shark sanctuaries), spatial planning methods managing human usage of areas of known shark and ray occurrence (e.g., protected areas or no take zones) or a combined approach to recognize areas contributing to biodiversity or ecological significance for sharks and rays (Shiffman & Hammerschlag, 2016). The Congolese government recently announced the creation of three new MPAs representing 12% of its EEZ. The government are also revising current fisheries laws, which will further strengthen protection of marine biodiversity and fisheries resources. However, alongside these actions, there is a need for the development of a national plan of action for sharks. This plan needs to consider both populations of sharks and rays, food security for coastal communities, and alignment to legislation to treaties and parties of which the Republic of the Congo is a signatory (e.g., CMS, CITES and CBD). Management strategies need to be underpinned by data to ensure appropriate policies are implemented. In the absence of detailed catch data and population estimates, setting sustainable catch limits or quotas is challenging. Size limits can be useful in fisheries where determining catch is difficult, with minimum landing sizes shown to be the most pragmatic strategy for shark fishing by limiting catch to only mature individuals (Smart et al., 2020). Due to the high prevalence of juveniles in the Congolese artisanal fishery, this approach would prove challenging and very difficult to monitor or enforce. We suggest applying a combined approach that considers compromise between restrictions and community-based use. Knowledge of presence and seasonality of specific species may aid this. Presenting fishers with information on more easily identifiable and highly threatened groups of species with similar morphology and appearance, such as guitarfish, wedgefish, and angel sharks may facilitate release from nets and reduce mortality rates. Furthermore, the two most observed species throughout this study, scalloped hammerhead and blacktip sharks, showed intra-annual variation where catch trends were much higher in the latter part of the year, within the short-wet and short-dry seasons. The timing of these catches corresponds with a reduction in overall shark catch. This may present an opportunity for gear-based restrictions or timed-closures within the short-wet and short-dry seasons to alleviate some pressure on these threatened species. This could be particularly beneficial for scalloped hammerhead sharks, where catch comprises mostly juveniles, indicative of parturition and/or nursery grounds. This approach will require continued work with the fishing community to disseminate information on observed catch and species presence. Furthermore, establishing best practices from complementary data collection is required. This may take the form of activities such as participatory mapping of areas where specific species are caught or satellite tracking studies to observe space-use within these waters to highlight where these key life-history events may be occurring will be hugely beneficial.

Despite often being referred to as small-scale, artisanal fleets such as the one described in this study can represent a substantial level of exploitation. The magnitude of which is of concern with regards to long-term sustainability. These findings further emphasize the need to develop long-term participatory projects with the artisanal fisheries sector in underreported areas to fill key knowledge gaps that may identify hotspots for otherwise imperiled species.

AUTHOR CONTRIBUTIONS

Philip D. Doherty: Conceptualization, methodology, data collection, formal analysis, writing, and visualization. **Godefroy De Bruyne**: Conceptualization, methodology, data collection, review, and editing. **Baudelaire Dissondet Moundzoho**: Data collection, methodology, logistics, review, and editing. **Emmanuel Dilambaka**: Data collection, methodology, logistics, review, and editing. **Gaston Ngassiki Okondza**: Governmental approval, logistics, review, and editing. **Benoit C. Atsango**: Governmental approval, logistics, review, and editing. **Appolinaire Ngouembe**: Logistics, review, and editing. **Tite R. Akendze**: Governmental approval, logistics, data collection, review, and editing. **Richard J. Parnell**: Conceptualization, review, and editing. **Morgane Cournarie**: Conceptualization, funding, logistics, review, and editing. **Richard Malonga**: Conceptualization, funding, logistics, review, and editing. **Antoine Missamou**: Governmental approval, logistics, review, and editing. **Brendan J. Godley**: Conceptualization, funding, review, and editing; **Kristian Metcalfe**: Conceptualization, funding, methodology, data collection, and writing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data used for this study are ongoing and are currently forming part of a larger program to update and inform legislation and a national plan of action for sharks and rays and therefore are the property of the Congolese government.

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