Impacts of Industrial Longline Fisheries on Elasmobranch Species Captured in Kenya's Exclusive Economic Zone

Kiilu, Benedict[1]; Ndegwa, Stephen[1]; Kimani, Edward[2]; Okemwa, Gladys[2]; Fulanda, Bernard[3]; Mueni, Elizabeth[1] and Wachira, Kelvin[1]

[1]Kenya Fisheries Service, P. O. Box 90423 code 80100, Mombasa, Kenya

[2]Kenya Marine and Fisheries Research Institute, P.O. Box 81651-80100, Mombasa, Kenya

[3]Department of Biological Sciences, Pwani University, P.O Box 195-80108, Kilifi Kenya

Abstract

This study presents the first comprehensive assessment of industrial longline fisheries and their interactions with elasmobranch species within Kenya's Exclusive Economic Zone (EEZ). It analyzes the spatial distribution of longline catches within Kenya's Exclusive Economic Zone (EEZ) and beyond, with a specific focus on the incidental capture of vulnerable shark species.

Utilizing fishing vessel logbooks and data from fisheries observer deployments (2016-2021) and reconstructed catch records from 1950 to 2020, we analyze spatial and temporal patterns of shark bycatch, species composition, and catch rates. We show that widespread industrial longline activity, with high catch areas nearshore and in offshore EEZ hotspots are inferred to overlap significantly with shark distribution, probably overlapping with shark aggregation areas.

Results further show that longline operations consistently capture vulnerable pelagic sharks, with *Prionace glauca* and *Carcharhinus falciformis* comprising over 85% of observed catches. Catch rates remained low (<0.05 pieces/1000 hooks/day) despite high effort. Depth-specific data indicate peak shark interactions between 50–150 meters, supporting the possible use of depth-based gear restrictions.

These findings underscore the urgent need for targeted bycatch mitigation, seasonal closures, and enhanced monitoring to safeguard threatened elasmobranch populations. The study provides vital evidence to inform implementation of Kenya's National Plan of Action for Sharks and compliance with Indian Ocean Tuna Commission (IOTC) Conservation and Management Measures.

Key words: ***Species distribution, sharks, longlines, seasonality, variability, bycatch mitigation***

1.0. Introduction

Fishing is the greatest threat to marine biodiversity including that of sharks and rays by routinely depleting marine fish populations by 50 to 70% (Baum et al., 2003) with losses exceeding 90% becoming common in some populations (Myers and Worm, 2005). Most of the sharks and rays (hereinafter sharks) are taken as bycatch in industrial fisheries, however, the volume of bycatch often exceeds that of target species leading to changes in food web relationships through excessive removal of top predators (Dulvy et al. 2021). Bycatch may also affect species composition, predator behavior, and catch rates of target species (Bonanomi et al. 2017) in addition to having socio-economic implications (Garth et al., 2015). Industrial longlines is one such fishery with increasing effects on marine ecosystems through the removal of bycatch species that often includes sharks and turtles (Gilman et al., 2008; Dapp et al., 2013) . However, although mitigation measures for controlling turtle bycatch have been relatively successful, sharks have continued to form a major bycatch of longline fishery targeting tuna and tuna-like species (Dulkvy et al., 2021). Shortfin mako sharks (*Isurus oxyrinchus*) blue shark (*Prionace glauca*) and silky shark (*Carcharhinus falciformis*), for example, suffer high fishing mortality throughout their range (Dulvy et al., 2008) as bycatch in longlinesLewison and Crowder, 2007; Myers *et al.*, 2007; Walace 2010),

Shark populations are sensitive to overfishing owing to the fact that sharks display an intrinsic sensitivity to mortality from fisheries because they exhibit life history traits such as low productivity, low fecundity and late age of maturity (Cope, 2006; Gilman *et al.*, 2008; Lewison and Crowder, 2007) that make them vulnerable to fishing mortality. Nonetheless, sharks play important ecological roles by regulating marine communities and providing stability to ecosystems through direct predation (Bascompte *et al.*, 2005; Myers *et al.*, 2007) and by controlling populations of mesopredators and dampening fisheries induced top-down cascades (Agardy, 2000; Baum and Worm, 2009; Myers *et al.*, 2007). Despite the socio-ecological importance of sharks, one-third (37%) of the species are threatened with extinction (Dulvy et al., 2021) with nearly 90% of the pelagic species in the Western Indian Ocean being threatened (Pacoureau et al., 2021). The situation in the WIO is worsened by the bycatch from the longline tuna fisheries that often catch large volumes of sharks as bycatch (Kiszka et al., 2010). Management of shark bycatch in longlines is often hampered by the lack of data on the operational, environmental and biological components of longline fleets (Dulvy et al., 2014). There is need to resolve the spatio-temporal distribution and catch rates of the species landed as is the need to determine variables such as soak time, hook types and depths in the operation of longlines in order to guide management..

Kenya’s marine fisheries are estimated at an annual maximum sustainable yield of 150,000 mt (Ruwa *et al.*, 2003) while the EEZ is estimated to have a potential annual harvestable fisheries biomass of about 321 262 tons (KMFRI, 2018). The annual nominal marine fisheries production is relatively low, with the 2024 total production (marine capture landings and mariculture) being 48,608 MT with an ex-vessel value of 15.2 billion Kenya shillings (~17.5 million USD) compared to 39,950 MT with an ex-vessel value of 9.9 billion Kenya shillings (~76.5 million USD) in 2023

(Government of Kenya, 2024). Artisanal fishery contributed 39,702 MT while industrial fishery contributed 8,772 MT. However, there is a substantial potential to produce about 150,000 - 300,000mt per annum valued at 21-42 billion shillings (~162.3 – 185.5 million USD) from increased exploitation of the EEZ resources (Government of Kenya, 2024).

The Kenyan longline fishery primarily operates in offshore waters, beyond the 12 nautical mile territorial sea limit and within the Kenyan Exclusive Economic Zone (EEZ) extending to 200 nautical miles and in the on the high seas outside the of the EEZ, and in other coastal States EEZs under a license arrangement. To develop its national fishing fleet, Kenya registered an initial three local longline fishing vessels between 2016 – 2021, while in 2022 – 2024 the number fluctuated between four to seven industrial longline vessels licensed to fish. . These vessels interact with sharks and often catch them, some of which are retained as bycatch. In most cases shark bycatch in the industrial longline fishery typically results in mortalities due to the fishing operations and handling stress, besides the retention of specimens for fin trade or local sale for meat (Benedict Kiilu, pers. obs.). Furthermore, despite the continued exploitation of sharks by the longline fleet, the composition proportion of shark species landed as bycatch and their spatio-temporal distribution are not known, but are important for compliance actions and enforcing monitoring, surveillance and control (MCS) regulations. .

This pioneering study carried out in Kenya fishery waters aimed to contribute useful information in managing the shark bycatch from tuna longline fishery on the Kenyan coast and the WIO region.

The study further aimed to address these gaps by: (i) determining the species composition and proportions of shark bycatch, (ii) describing the spatial and temporal patterns of fishing effort and catch rates, and (iii) examining changing size distributions among sharks landed along coastal Kenya.

2.0. Materials and methods

The materials and methods used for this study were designed to capture, analyze, and interpret data on shark bycatch within Kenya's industrial longline fishery. The data was derived from observer records, fishery independent research cruises, and vessel logbooks.

2.1. Study area and data set

The Kenya marine waters extend from the Somalia border (1° 30'S) to Tanzania (5° 25'S) and covers an exclusive economic zone (EEZ) which stretches up to 200 nautical miles with an area covering about 230,000 km^2 (Fulanda *et al.*, 2011; Munga *et al.*, 2013) (Fig. 1). The environmental conditions are influenced by two monsoon seasons that drive ocean currents, winds, and other climatic factors. The northeast monsoon (NEM), lasts from October to March, and the southeast monsoon (SEM) prevails from April to September (McClanahan, 1988). March-April and October-November are regarded as transition periods, locally referred to as *Matlai*, when the winds change direction from NE to SE and vice versa, and are characterized by winds with lower speed and more variable direction (Schott *et al.*, 2009 McClanahan, 1988).

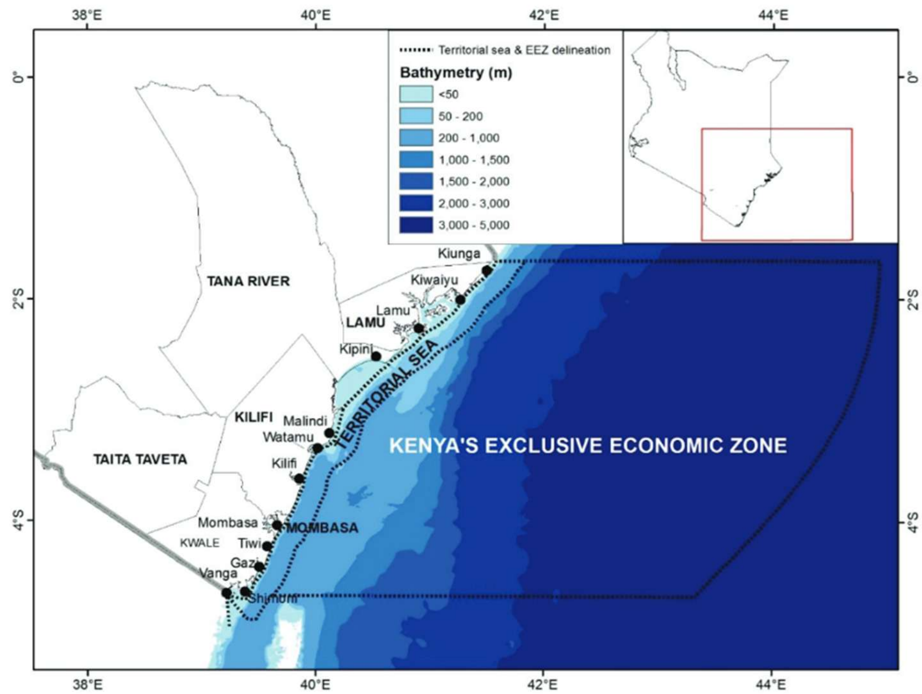

Figure 1: Map of Kenya's Exclusive Economic Zone (EEZ) with showing the bathymetry and coastal counties delineations

2.2. Reconstructed catch landings

Kenya's national fisheries statistics prior to 2000 are sparse, fragmented, or aggregated as merely "sharks and rays." Shark catches especially those from artisanal and small-scale fisheries were rarely disaggregated by species or gear type. In addition, observer coverage has historically been low prior to 2016, limiting availability of actual catch landings and composition in the industrial fisheries.

To visualize sharks catch trends over time and hence track the historical catch trajectories, we compiled shark and ray landing data spanning 1950–2020 from multiple sources. These sources included reconstructed landings (1950–2014) derived using the Sea Around Us and Reported landings (2000–2020) extracted from Kenya's official fisheries statistics and FAO datasets.

2.3. Observer program and catch data

The Kenya longline fishery observer monitoring was initiated in 2016, and monitoring has been continuous, with the exception of 2020, during the peak of the Covid-19 pandemic. Observers remained on fishing vessels throughout a voyage while trips typically lasted about two weeks to 2 months.

In addition, over the study period, longline fishing vessels were flagged or licensed on various dates, and therefore the observer catch records were not continuous over the months for each vessel. On each vessel on those varying dates, an observer was deployed and recorded the vessel name, geo-location of starting and finishing line deployment, start and finishing location of longline recovery, depth of hooks , set and haul back time , the number of hooks deployed per line, number and the total weight of target fish caught, species name, sex and morphometric measurements of bycatch sharks. Lengths were visually estimated for the legally protected sharks (e.g. *Alopius* spp., oceanic whitetip sharks) that could not be onboarded. All fishing vessels used circle hooks baited mainly with Indian mackerel, *Rastrelliger kanagurta ,* or occasionally whole cuttlefish, and without offset..

2.4. Catch rates

Catch per unit effort (CPUE) was defined as number of sharks caught per 1000 hooks set, calculated according to Godoy *et al.* (2003);

$$\frac{\sum n}{\sum h \text{ x } \sum t} \text{ X } 1000,$$

Where, n is the number of individuals, h the number of hooks per line and t the number of sets.

Mean annual catch rate of the species were compared between the years (2016-2021) using one-way ANOVA on log transformed catch rates to normalize the data due to the wide range and skewness in the catch rates.

2.5. Effort distribution and species composition

The distribution of the fishing effort (number of vessels per 1° grid) were plotted on a base map using QGis version 3.40 and catch rates of the species (number per 1000 hooks set) tabulated to normalize catch data across the vessels and compare their CPUEs.

The vertical habitat preferences and catch concentration were also determined by comparing depth and numbers of sharks captured, to inform the possibility of depth-based gear restrictions that could help reduce bycatch of vulnerable and threatened sharks.

3.0. Results

3.1. Impacts of fishing: Catch reconstruction

Reconstructed Kenya's shark and ray fisheries landings over seven decades (1950–2020) (Fig. 2) reveals both ecological and economic dynamics, with landings showing a steady rise from 1950, peaking dramatically at ~3100 MT in 1978, then a sharp crash to ~640 MT by 1984, possibly due to overfishing, regulatory shifts, or ecosystem changes. Post 1984 there is a fluctuating but generally declining trend, reaching bottom at ~490 MT in 2012. The landings then stabilize until 2012, then a surge to ~1900 MT in 2014, followed by a drop to ~750 MT in 2020. This post 2012 trend may reflect improved reporting as Kenya's fisheries management system kept improving, changes in market demand, and therefore changes in fishing effort (Fig. 2).

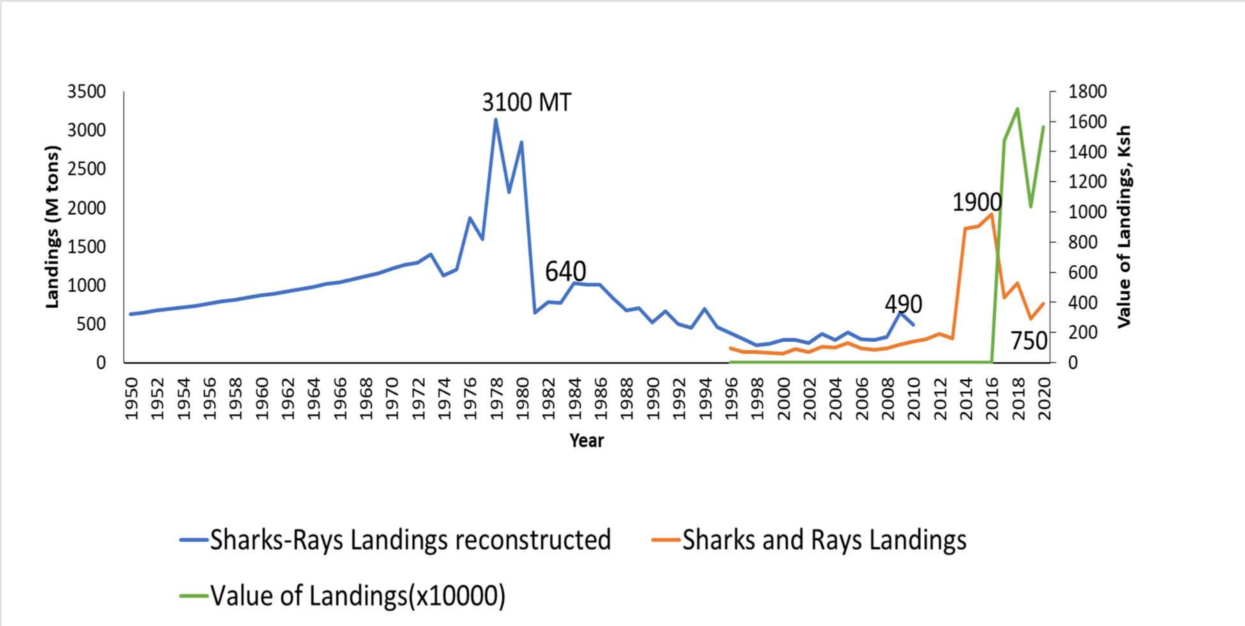

Figure 2: Historical Trends in Shark and Ray Landings and Their Economic Value (1950–2020)

Figure 2 further shows that economic value was minimal until around 2014–2012, then a sharp rise to ~Ksh 1.6 million (~12,300 USD) in 2016, peaking in 2017 at ~Ksh 1.7 million (~13,100 USD), almost mirroring the landings spikes. Then there were reported slight declines thereafter, settling at ~Ksh 1.1 million (~8,500 USD) in 2019, rising to ~Ksh 1.6 million (~12,300 USD). This may suggest ecological Pressure due to unsustainable exploitation as shown in the 1978 peak followed by collapse.

3.2. Effort distribution and species composition

We found that the Kenyan longline fishery interacted directly with sixteen species of sharks and rays. Furthermore, a total of 10,938,936 hooks were fished on 7,057 longline sets over the study period (Table 2). The database for analyses included 1,848 longline sets that caught a total of 7,739 sharks of 6 species on 2,653,965 hooks. There was also a significant number (61 pieces) of unidentified shark species categorized as “others”.

The spatial distribution of fishing vessels effort and the sharks species composition proportions during the study period are shown in Fig. 3. There is a spatial overlap between vessel effort hotspots and the dominance of sharks particularly *Prionace glauca*, pointing to possible ecological preferences and fleet behavior. *P. glauca* and *Carcharhinus falciformis* sharks are known to aggregate in warm, productive offshore waters (Queiroz et al., 2016; Wambiji et al., 2022), which matches the southern EEZ hotspots in 2016–2021. The vessel effort hotspots are also concentrated in offshore southern EEZ zones, suggesting targeted effort or migratory aggregations of pelagic sharks like *Prionace glauca* and *Carcharhinus falciformis.*

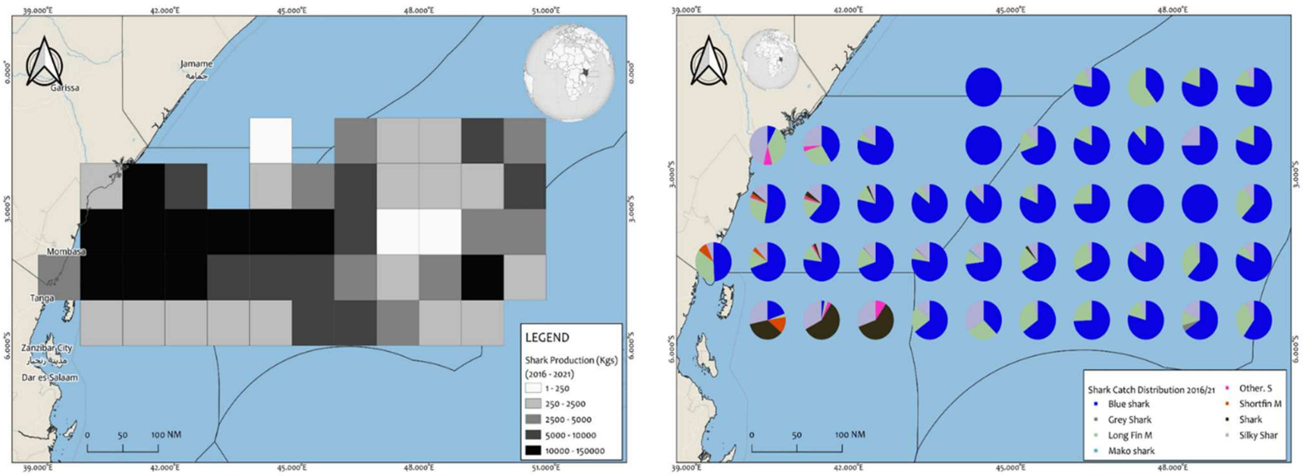

Figure 3: Spatial distribution of longline fishing vessel effort (left panel) and species composition of shark catches (right panel) in Kenya's Exclusive Economic Zone (EEZ).

Evidently *Carcharhinus falciformis* (silky shark) and *Prionace glauca* (blue shark) appear to constitute the bulk of catches, while the presence of *Isurus oxyrinchus* (shortfin mako) and *Carcharhinus longimanus* (oceanic whitetip shark) suggests interactions with vulnerable or IUCN-listed species.

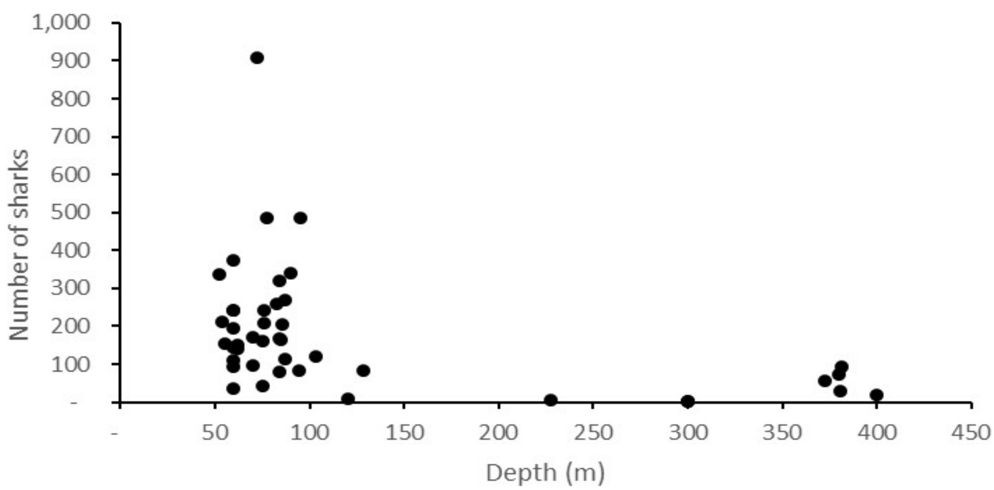

Fig. 5: Shark catches in relation to depth (m) of line setting

High numbers of sharks were caught at water depths of less than 150m. The highest catch densities were observed between 50 and 150 meters, with a peak around 100 meters. Beyond 150 meters, shark catches dropped sharply, with only sparse occurrences between 300–450 meters.

3.3. Species-specific catch rates and catch trends

A total of 2,667,345 hooks were deployed during the study period (2016–2021). With an aggregate total fishing time of 43,647.81 hours and 7,739 shark pieces caught, the average catch rates were low overall, often < 0.05 pieces/1000 hooks/day, indicating low shark abundance or low gear selectivity (Table 1).

Table 1: Shark catch-rates, 2016–2021

Year	Species	Number of shark pieces caught	Number of hooks used	Fishing Time (hrs)	Catch rate (pieces/1000 hooks/day)
2016	Other sharks	113	7,500	94.08	3.84
2017	*Carcharhinus limbatus*	58	37,895	124.45	0.30
	Prionace glauca	111	103,755	317.01	0.08
	Sphyrna lewini	8	14,700	62.03	0.21
2018	*Carcharhinus falciformis*	234	133,938	1,323.05	0.03
	Isurus oxyrinchus	121	76,008	3,733.39	0.01
	Isurus paucus	20	28,974	292.24	0.06
	Prionace glauca	1,202	352,559	7,010.58	0.01
	Other sharks	117	125,256	445.07	0.05
2019	*Carcharhinus falciformis*	368	257,155	2,734.15	0.01
	Isurus oxyrinchus	114	85,989	1,670.55	0.02
	Isurus paucus	168	150,212	2,449.55	0.01
	Prionace glauca	2,798	503,384	8,613.36	0.02
	Other sharks	19	27,000	198.33	0.09
2020	*Carcharhinus falciformis*	656	270,191	3,945.12	0.01
	Isurus oxyrinchus	53	43,962	876.00	0.03
	Isurus paucus	225	175,214	3,854.05	0.01
	Prionace glauca	1,316	257,693	5,620.40	0.02
	Other sharks	1	2,700	20.20	0.44
2021	*Carcharhinus falciformis*	6	3,615	72.20	0.55
	Isurus paucus	13	6,030	119.50	0.43
	Prionace glauca	18	3,615	72.50	1.65
	Total	**7,739**	**2,667,345**	**43,647.81**	

The year 2016 showed the highest catch rate, most likely attributed to lower effort and less gear saturation while the years 2018–2020 show plummeting catch rates despite massive effort (millions of hooks) (Table 1) probably due to shifts in spatial distribution brought about by seasons or other oceanographic parameters. In 2021 the effort significantly drops, but catch rate is high possibly due to reduced competition after Covid-19.

One-way ANOVA test on log-transformed catch rates conducted to assess whether mean annual catch rates differ significantly across years, results showed the F-statistic as 9.1530 and a p-value of 0.0003 which is a low p-value (< 0.05), indicating strong evidence that there are statistically significant differences in mean catch rates between years. Thus, fishing efficiency (as measured by catch rate per 1000 hooks/day) varied significantly across the 6-year period, potentially due to: Shifts in species abundance or distribution, Changes in gear deployment or effort, Regulatory interventions or fleet behavior, Environmental or oceanographic conditions

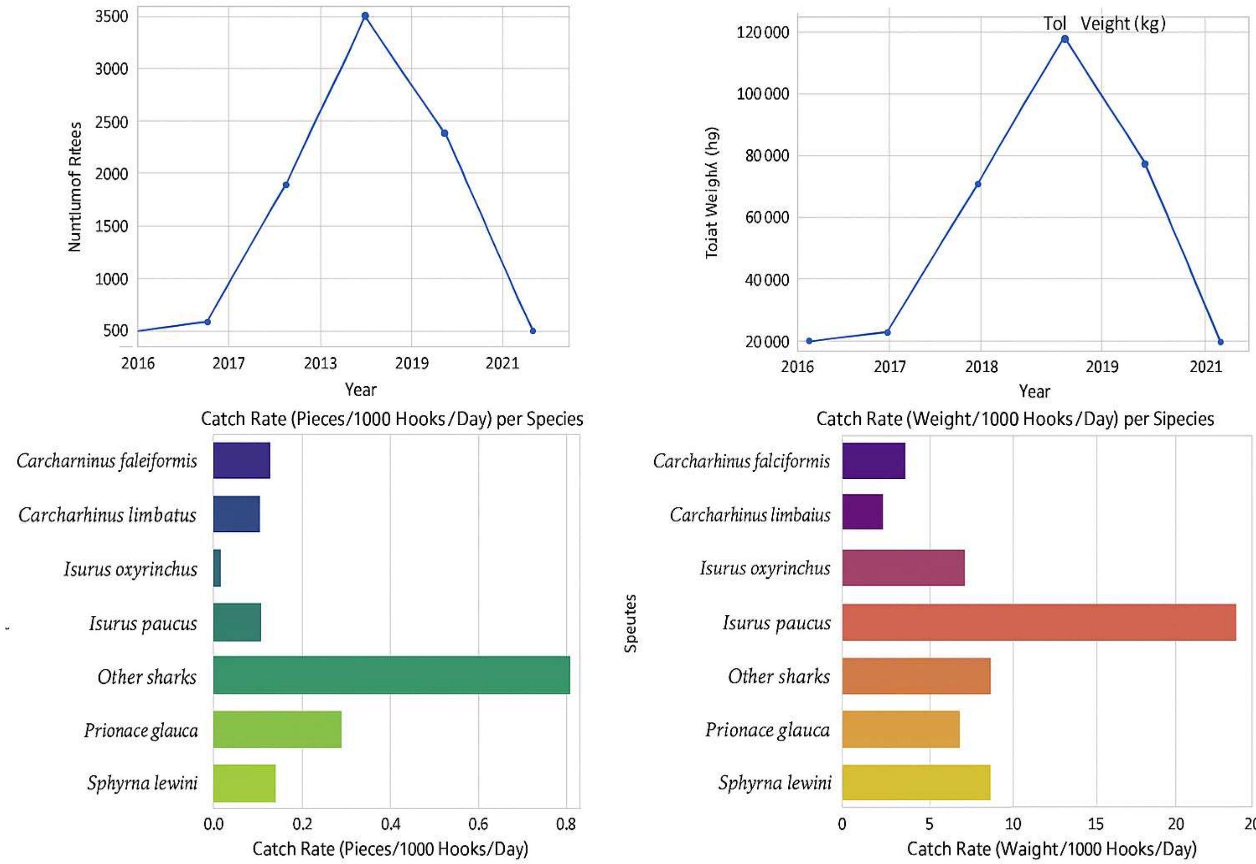

Figure 3: Annual sharks catch trends and species-specific catch rates (2016–2021)

The line charts in Figure 3 above show how shark catches by numbers (left panel) and by weight (right panel) have fluctuated annually from 2016 to 2021, highlighting 2019 as the peak year and potential declines or shifts in targeting. They offer a glimpse for assessing biomass extraction trends while comparing with effort metrics like hooks deployed and fishing hours.

The horizontal bar charts rank species by average catch rate, revealing which sharks are most frequently caught relative to effort, offering valuable insights in identifying high-interaction species like *Prionace glauca* and *Isurus paucus*.

Figure 4 illustrates the temporal catch patterns of five shark species across the months (January–November) taken as average numbers over the period 2016–2021. *P. glauca* exhibited the highest monthly catch across all species and a consistent presence over the months indicating year-round availability. Overall, the months of May and June emerge as a critical period for shark interactions, especially for the *Prionace glauca* and *Isurus oxyrinchus*.

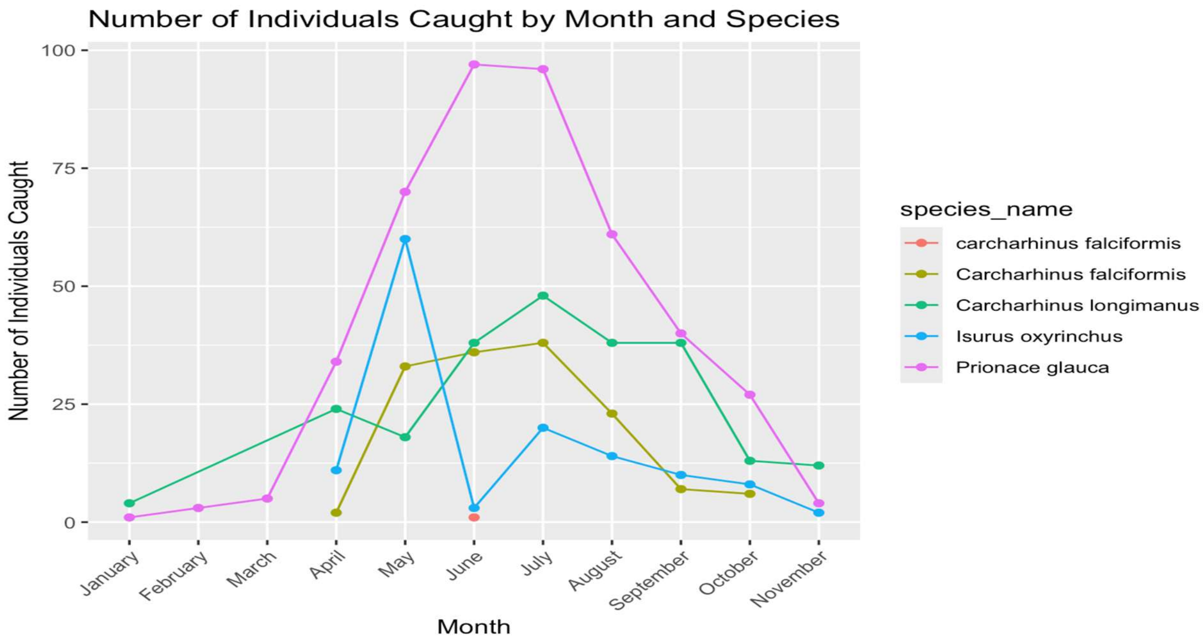

Figure 4: Monthly catch trends of selected shark species in Kenya's Exclusive Economic Zone (EEZ) based on longline fisheries data (January–November)

4.0. Discussion

This study provides the first comprehensive assessment of Kenya's industrial longline interactions with elasmobranch species in the Exclusive Economic Zone (EEZ). The results highlight significant ecological and management implications.

The reconstructed catch data spanning from 1950–2020 illustrates a varying trajectory, with landings peaking at 3,100 MT in 1978 before collapsing to 640 MT in 1984. Such a pattern is consistent with the global shark population declines driven by industrial fishing pressure and ecosystem shifts (Baum et al., 2003; Myers and Worm, 2005).

The catch rates from 2018–2020 remained low (<0.05 pieces/1000 hooks/day), probably due reduced abundance or declining gear selectivity. These trends mirror findings by Dulvy et al. (2021), who reported widespread declines in catch efficiency across overexploited shark populations. The dominance of *Prionace glauca* and *Carcharhinus falciformis* in longline sets aligns with their known pelagic distribution and susceptibility to longline gear (Queiroz et al., 2016; Cortés et al., 2010), while the presence of *Isurus* spp. and *Carcharhinus longimanus* highlights interactions with IUCN-listed vulnerable species (Dulvy et al., 2008; Pacoureau et al., 2021).

Spatial analysis revealed concentrated vessel effort in southern offshore EEZ zones and off the EEZ, overlapping with possible shark aggregation hotspots. This could imply targeted fishing in ecologically sensitive areas, potentially linked to migratory behavior or productive oceanographic features (Wambiji et al., 2022). Seasonal peaks in shark catches particularly in April, May, and July may correspond to spawning or feeding aggregations, pointing to the need for time-area closures and seasonal monitoring (Watson et al., 2009; Simpfendorfer & Dulvy, 2017).

Depth-specific catch data showed that most shark interactions occurred between 50–150 meters, with a steep decline beyond 150 meters. This vertical habitat preference supports the possibility of depth-based gear zoning to reduce bycatch of vulnerable elasmobranchs, especially juveniles and breeding stock (Ward-Paige et al., 2012; Rigby et al., 2019). If species-level data are available, this depth profile could further be cross-referenced with IUCN status to identify high-risk interactions (e.g. *Carcharhinus longimanus* or *Isurus* spp.).

Given the life history traits of sharks including slow growth, late maturity, and low fecundity, their populations are intrinsically vulnerable to overfishing (Cope, 2006; Dulvy et al., 2014). Without targeted management, the risk of population collapse remains significantly high, with potential trophic cascades and ecosystem disruption (Borer et al., 2005; Ferretti et al., 2010).

5.0. Conclusion and recommendations

The current harvest levels of sharks in Kenya mean that there is potential of exposing the populations to high declines, and recovery is unlikely for the majority of species if depleted. Development of a sustainable fishery will require both immediate steps to reduce the impact of the fishery and long-term scientific studies and stock assessments of the fish populations to more accurately determine the best strategies to restore and maintain them (Branch *et al.*, 2011).

It is most likely the implications of current overfishing of sharks by the Kenya longline fleets may not be clear for many years to come. Questions need to be asked on whether there will be a trophic cascade, in which removal of a top predator has effects far down a food web (Borer *et al.*, 2005), due to the decline of shark populations, and whether more research, and of what type is required. For example, more research is required to determine whether blue shark populations, which is most predominantly caught, remain abundant or will decline, and if the decline affect other shark species of the same trophic level or other species lower down the food web. Our findings suggest that the populations of sharks affected by the longline fishery may be in danger of collapse and that there are insufficient scientific data to predict whether and when such a collapse will occur, and exactly in which species.

The findings in this study reinforce the critical need of implementing Kenya’s National Plan of Action for Sharks (NPOA-Sharks) and aligning actions with Indian Ocean Tuna Commission (IOTC) Conservation and Management Measures (CMMs). Recommended interventions include seasonal closures during peak shark interaction months, depth-based gear restrictions, and enhanced observer coverage. These measures, if effectively enforced, could significantly reduce bycatch and support the recovery of threatened elasmobranch populations (Carlson et al., 2012; Simpfendorfer et al., 2011).

Offshore area and seasonal closures would be effective in reducing the bycatch of sharks as the vessels target the tuna and tuna-like stocks. Establishment and effective enforcement of no-take marine protected area would greatly reduce shark bycatch. Another approach would be to enforce a time-area closure of the fishing season during the peak breeding season of the blue sharks in the WIO.

This approach would also control the large unregulated artisanal fishery, owing to the fact that pelagic sharks and rays are subject to high and often unrestricted levels of mortality from bycatch and targeted fisheries throughout the oceans (Baum*et al.*, 2003).

Protection is needed for the nursery area of hammerhead sharks. That in turn would also protect other sharks and rays species that may use the bay for breeding or feeding grounds for their young.. In the case of blue sharks and mako sharks, spatial closures of the offshore tuna fishery would minimize catch of juveniles or breeding stock (Watson *et al.*, 2009). It is unknown what effect this would have on other bycatch species such as pelagic thresher sharks, but it would significantly reduce silky shark and oceanic whitetip that are all protected under the Indian Ocean Tuna Commission Conservation and Management Measures (IOTC CMMs).

Another approach would be to enact seasonal closures of the billfish fishery, closing the fishery when billfishes are not in season and when shark catch is greatest. Finally, decreasing soak times of longlines can decrease catch rate of blue sharks, mako sharks, silky sharks, thresher sharks etc. With strengthened management and protection of shark species in Kenyan waters, it should be possible to ameliorate the stresses caused to shark populations by the longline fisheries.

6.0. References

Arrizabalaga, H., de Bruyn, P., Diaz, G. A., Murua, H., Chavance, P., de Molina, A. D., … Kell, L. T. (2011). Productivity and susceptibility analysis for species caught in Atlantic tuna fisheries. *Aquatic Living Resources*, *24*(1), 1–12. https://doi.org/10.1051/alr/2011007

Baum, J. K., Myers, R. A., Kehler, D. G., Worm, B., Harley, S. J., & Doherty, P. A. (2003). Collapse and Conservation of Shark Populations in the Northwest Atlantic. *Science*, *299*(5605), 389–392. https://doi.org/10.1126/science.1079777

Berkeley, S. A., and W. L. Campos. 1988. Relative abundance and fishery potential of pelagic sharks along Florida's east coast. Mar. Fish. Rev. 50(1):9-16.

Borer, E.T., Seabloom, E.W., Shurin, J.B., Anderson, K.E., Blanchette, C.A., Broitman, B., Cooper S.D. and Halpern B.S. (2005). What determines the strength of a trophic cascade? Ecological Society of America; Volume 86, Issue 2. **https://doi.org/10.1890/03-0816**

Braccini, J. M., Gillanders, B. M., & Walker, T. I. (2006). Hierarchical approach to the assessment of fishing effects on non-target chondrichthyans: case study of *Squalus megalops* in southeastern Australia. *Canadian Journal of Fisheries and Aquatic Sciences*, *63*(11), 2456–2466. https://doi.org/10.1139/f06-141

Branstetter, S. 1981a. Shark fishery potential for the northern Gulf of Mexico. Dauphin lsI. Sea Lab. (Ala.) Tech. Rep. 81-001, 21 p.

Branstetter, S. 1981b. Biological notes on the sharks of the north-central Gulf of Mexico. Contrib. Mar. Sci. 24: 13-34.

Carlson, J.K., Hale, L.F., Morgan, A. and Burgess, G (2012). Relative abundance and size of coastal sharks derived from commercial shark longline catch and effort data. J Fish Biol. 2012 Apr;80(5):1749-64. doi: 10.1111/j.1095-8649.2011.03193.x. Epub 2012 Jan 18. PMID: 22497406.

Clarke, S. C., McAllister, M. K., Milner-Gulland, E. J., Kirkwood, G. P., Michielsens, C. G. J., Agnew, D. J., … Shivji, M. S. (2006). Global estimates of shark catches using trade records from commercial markets. Ecology Letters, 9(10), 1115–1126. https://doi.org/10.1111/j.1461-0248.2006.00968.x

Colvocoresses, J. A., and J. A. Musick. 1980. A preliminary evaluation of the potential for a shark fishery in Virginia. VIMS Spec. Sci. Rep., App\. Mar. Sci., Ocean. Engr. 234, 39 p.

Cope, J.M. (2006). Exploring intraspecific life history patterns in sharks. Fish. Bull. 104:311-320.

Cortés, E., Arocha, F., Beerkircher, L., Carvalho, F., Domingo, A., Heupel, M., … Simpfendorfer, C. (2010). Ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries. *Aquatic Living Resources*, *23*(1), 25–34. https://doi.org/10.1051/alr/2009044

Davidson, L. N. K. L. K., Krawchuk, M. A. M., & Dulvy, N. K. N. N. K. (2016). Why have global shark and ray landings declined: Improved management or overfishing? *Fish and Fisheries*, *17*(2), 438–458. https://doi.org/10.1111/faf.12119

Dent, F., & Clarke, S. (2014). State of the Global Market for Shark Commodities (Vol. 590).

Dharmadi, Fahmi, & Satria, F. (2015). Fisheries management and conservation of sharks in Indonesia. *African Journal of Marine Science*, *37*(2), 249–258. https://doi.org/10.2989/1814232X.2015.1045431

Dulvy N.K., Pacoureau N., Rigby C.L., Pollom R.A., Jabado R.W., Ebert D.A., Finucci B., Pollock C.M., Cheok J., Derrick D.H., Herman K.B., Sherman C.S., VanderWright W.J., Lawson J.M., Walls R.H.L., Carlson J.K., Charvet P., Bineesh K.K., Fernando D., Ralph G.M., Matsushiba J.H., Hilton-Taylor C., Fordham S.V., Simpfendorfer C.A. 2021. Overfishing drives over one-third of all sharks and rays toward a global extinction crisis; Current Biology, Volume 31, Issue 21, Pages 4773-4787.e8, ISSN 0960-9822; https://doi.org/10.1016/j.cub.2021.08.062.

Dulvy, N. K., Baum, J. K., Clarke, S., Compagno, L. J. V., Cortés, E., Domingo, A., … Valenti, S. (2008). You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *18*(5), 459–482. 922 https://doi.org/10.1002/aqc.975

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., … White, W. T. (2014). Extinction risk and conservation of the world's sharks and rays. ELife, 3. https://doi.org/10.7554/eLife.00590

Dulvy, N. K., Simpfendorfer, C. A., Davidson, L. N. K., Fordham, S. V, Bräutigam, A., Sant, G., & Welch, D. J. (2017). Challenges and Priorities in Shark and Ray Conservation. *Current Biology: CB*, *27*(11), R565–R572. https://doi.org/10.1016/j.cub.2017.04.038

Ferretti, F., Worm, B., Britten, G. G. L., Heithaus, M. R. M., & Lotze, H. H. K. (2010). Patterns and ecosystem consequences of shark declines in the ocean. *Ecology Letters*, *13*(8), 1055–1071. https://doi.org/10.1111/j.1461-0248.2010.01489.x

Froese, R. and D. Pauly (eds.). 2000. FishBase 2000, concepts, design and data sources. ICLARM Contrib. No.1594. International Center for Living Aquatic Resources Management (ICLARM). Los Banos, Laguna, Philippines. 344 p.

Fulanda, B., Ohtomi, J., Mueni, E., Kimani, E., 2011. Fishery trends, resource-use, and management system in the ungwana bay fishery kenya. Ocean Coast. Manag. 54 (5), 401–414.

Garth C., Alasdair H., Frances H., Simon H. and Thomas T.2015. A preliminary value chain analysis of shark fisheries in Madagascar. A publication of the Indian Ocean Commission (IOC-SmartFish Project, 2015)Bonanomi, S., Brčić', J., Colombelli, A., Notti, E., Pulcinella, J. and Sala, A. 2017. Fisheries Bycatch of Chondrichthyes. InTech. doi: 10.5772/intechopen.69334Musick, 1. A., S. Branstetter, and 1. A. Colvocoresses. 1993. Trends in shark abundance from 1974-1991 for the Chesapeake Bight region of U.S. mid-Atlantic coast. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 115:1-18.

Glaus, K. B. J., Adrian-Kalchhauser, I., Piovano, S., Appleyard, S. A., Brunnschweiler, J. M., & Rico, C. (2018). Fishing for profit or food? Socio-economic drivers and fishers' attitudes towards sharks in Fiji. *Marine Policy*, (May), 1–9. https://doi.org/10.1016/j.marpol.2018.11.037

Government of Kenya, 2024. Fisheries Statistical Bulletin 2024; Ministry of Mining, Blue Economy and Maritime Affairs; Kenya Fisheries Service. May 2025 Issue.

Jaiteh, V., Loneragan, N., & Warren, C. (2017). The end of shark finning? Impacts of declining catches and fin demand on coastal community livelihoods. *Marine Policy*, *82* (March), 224–233. https://doi.org/10.1016/j.marpol.2017.03.027

James, K., Lewison, R. L., Dillingham, P., & Moore, J. E. (2016). Drivers of retention and discards of elasmobranch non-target catch. *Environmental Conservation*, *43*(1), 3–12. https://doi.org/10.1017/S0376892915000168

Kiszka, J., Bein, A., Bach, P., Jamon, A., Layssac, K., Labart, S., Wickel, J. 2010a. Catch and bycatch in the pelagic longline fishery around Mayotte (NE Mozambique Channel), July 2009-September

2010. Report to the Working Party on Ecosystems and Bycatch, Indian Ocean Tuna Commission. 6p.

KMFRI, 2018. In: Njiru, J.M., Ruwa, R.K., Kimani, E.N., Ong'anda, H.O., Okemwa, G.M., Osore, M.K. (Eds.), The RV Mtafiti: Marine Research towards Food Security and Economic Development for Kenya. Kenya Marine and Fisheries Research Institute, Mombasa, Kenya, p. 102.

Lack, M., & Sant, G. (2011). The future of sharks: a review of action and inaction. TRAFFIC International and the Pew Environment Group.

Leeney, R. H., & Poncelet, P. (2015). Using fishers' ecological knowledge to assess the status and cultural importance of sawfish in Guinea-Bissau. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *25*(3), 411–430. https://doi.org/10.1002/aqc.2419

Leeney, R., Mana, R., & Dulvy, N. (2018). Fishers' ecological knowledge of sawfishes in the Sepik and Ramu rivers, northern Papua New Guinea. *Endangered Species Research*, *36*, 15–26. https://doi.org/10.3354/esr00887

Lestari, W., Sayuti, M., Muhsin, Akbar, B., Sundari, E., & Isnaini. (2017). [Socio economic study of shark fishers in Tanjung Luar, East Lombok, West Nusa Tenggara]. Wildlife Conservation Society–Indonesia Program.

MacKeracher, T., Diedrich, A., & Simpfendorfer, C. A. (2018). Sharks, rays and marine protected areas: A critical evaluation of current perspectives. *Fish and Fisheries*. https://doi.org/10.1111/faf.12337

McClanahan T. 1988. Seasonality in East Africa's coastal waters. Marine Ecology Progress Series 44: 191-199

Momigliano, P., & Harcourt, R. (2014). Shark conservation, governance and management: The science-law disconnect. In N. Klein & E. Techera (Eds.), *Sharks: conservation, governance and management* (pp. 89–106). Abingdon, UK: Earthscan Series. https://doi.org/10.4324/9780203750292

Munga, C.N., Mwangi, S., Ong'anda, H., Ruwa, R., Manyala, J., Groeneveld, J.C. and Vanreusel, A., 2013. Species composition, distribution patterns and population structure of penaeid shrimps in Malindi-Ungwana bay, Kenya, based on experimental bottom trawl surveys. Fish. Res. 147, 93–102.

Musick, J., Burgess, G., Cailliet, G., Camhi, M., & Fordham, S. (2000). Management of Sharks and Their Relatives (Elasmobranchii). *Fisheries*, 9–13. Retrieved from http://www.adfg.alaska.gov/static-1118 sf/Region2/ground_fish/PDFs/AFSMarineStocksAtRisk31b_sharks.pdf

Myers, R.A. and Worm, B. (2005). Extinction, survival or recovery of large predatory fishes. Philosophical Transactions of the Royal Society, B: Biological Sciences, 360(1453), 13–20.

Nina Wambiji, Nelly Isigi Kadagi, Bernadine I. Everett, Andrew J. Temple, Jeremy J. Kiszka, Edward Kimani and Per Berggren (2022). Integrating long-term citizen science data and contemporary artisanal fishery survey data to investigate recreational and small-scale shark fisheries in Kenya. https://doi.org/10.1002/aqc.3829

Obura, D.O., 2001. Participatory monitoring of shallow tropical marine fisheries by artisanal fishers in Diani, Kenya. Bull. Mar. Sci. 69 (2), 777–791.

Okoola, R. (1998) Characteristics of the ITCZ over equatorial Eastern Africa based on station rainfall records. Journal of African Meteorology. Soc.,3, 61-101, http://profiles.uonbi.ac.ke/rokoola/publications/characteristics-itcz-over-equatorial-eastern-africa-based-station-rainfall-reco

Oliver, S., Braccini, M., Newman, S. J., & Harvey, E. S. (2015). Global patterns in the bycatch of sharks and rays. Marine Policy, 54, 86–97. https://doi.org/10.1016/j.marpol.2014.12.017

Queiroz N., Humphries N.E., Mucientes G., Hammerschlag N., Lima F.P., Scales K.L., Miller P.I., Sousa L.L., Seabra R. and Sims D.W. (2016). Ocean-wide tracking of pelagic sharks reveals extent of overlap with longline fishing hotspots, Proc. Natl. Acad. Sci. U.S.A. 113 (6) 1582-1587, https://doi.org/10.1073/pnas.1510090113 (2016).

Rigby, C., Appleyard, S., Chin, A., Heupel, M., Humber, F., Jeffers, V., … Campbell, I. (2019). *Rapid Assessment Toolkit for Sharks and Rays*. Retrieved from https://sharks.panda.org/images/RAT/pdf/WWF_RapidAssessmentToolkitSharksRays_2011148_9_V10.pdf

Schott, F.A., S. P. Xie, and J. P. McCreary Jr. (2009), Indian Ocean circulation and climate variability, Rev. Geophys., 47, RG1002, doi:10.1029/2007RG000245

Simpfendorfer, C., & Dulvy, N. K. (2017). Bright spots of sustainable shark fishing. *Current Biology*, *27*(3), R97–R98. https://doi.org/10.1016/j.cub.2016.12.017

Simpfendorfer, C., Heupel, M., White, W. T., & Dulvy, N. K. (2011). The importance of research and public opinion to conservation management of sharks and rays: A synthesis. *Marine and Freshwater Research*, *62*(6), 518–527. https://doi.org/10.1071/MF11086

Snedecor, G. W., and W. G. Cochran. 1980. Statistical methods (7th ed.). Iowa State Univ. Press, Ames, 507 p.

Stein, R. W., Mull, C. G., Kuhn, T. S., Aschliman, N. C., Davidson, L. N. K., Joy, J. B., … Mooers, A. O. (2018). Global priorities for conserving the evolutionary history of sharks, rays and chimaeras. *Nature Ecology and Evolution*. https://doi.org/10.1038/s41559-017-0448-4

Stevens, J., Bonfil, R., Dulvy, N. K., & Walker, P. A. P. (2000). The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. ICES Journal of Marine Science, 57(3), 476–494. https://doi.org/10.1006/jmsc.2000.0724

Stevens, J., Bonfil, R., Dulvy, N. K., & Walker, P. A. P. (2000). The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science*, *57*(3), 476–494. https://doi.org/10.1006/jmsc.2000.0724

UNEP, 1998. Environment for development annual report 1998.

Ward-Paige, C. A., Keith, D. M., & Lotze, H. K. (2012). Recovery potential and conservation options for elasmobranchs. Journal of Fish Biology, 80, 1844–1869. https://doi.org/10.1111/j.1095-8649.2012.03246.x

Watson JW, Epperly SO, Shah AK, Foster DG (2005) Fishing methods to reduce sea turtle mortality associated with pelagic longlines. Can J Fish Aquat Sci 62:965–981

White, W. T., & Last, P. R. (2012). A review of the taxonomy of chondrichthyan fishes: a modern perspective. *Journal of Fish Biology*, *80*, 901–917. https://doi.org/10.1111/j.1095-8649.2011.03192.x

Worm, B., Davis, B., Kettemer, L., Ward-Paige, C. A., Chapman, D., Heithaus, M. R., … Gruber, S. H. (2013). Global catches, exploitation rates, and rebuilding options for sharks. Marine Policy, 40, 194–204. https://doi.org/10.1016/j.marpol.2012.12.034

Yulianto, I., Booth, H., Ningtias, P., Kartawijaya, T., Santos, J., Sarmintohadi, … Hammer, C. (2018). Practical measures for sustainable shark fisheries: Lessons learned from an Indonesian targeted shark fishery. *PLOS ONE*, *13*(11), e0206437. https://doi.org/10.1371/journal.pone.0206437