Semi-quantitative risk assessment of Chondrichthyan species from coastal Kenya using Productivity and Susceptibility Analysis (PSA)

Vulnerability risk assessment of chondrichthyan species caught off the Kenyan coast: implications for management

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Abstract

Quantitative assessments of shark populations are difficult to undertake due to the scarcity of data, and the studies focusing on species identification and landings are limited in the Western Indian Ocean (WIO) region. Productivity and susceptibility analysis (PSA) were used to examine the impact of the artisanal, bottom trawl and longline fishery on 44 shark species, 38 ray species, seven (7) guitarfish species, three (3) sawfish species, one (1) wedgefish species and one (1) skate species, captured and landed off the Kenyan coast. The IUCN status listings of the assessed species were then compared with the PSA findings to assess efficacy of the PSA in the determination of vulnerability.

One (1) species of ray caught in the artisanal fishery, *Neotrygon caeruleopunctata* (Bluespotted maskray), was reported as at high risk, with six (6) ray species found to be at medium risk. Similarly, one (1) shark species was rated to be at high risk in the trawl fishery, while only three 3 rays 15 shark species, two sawfish species and two guitarfish species were ranked as high risk in the trawl fishery. In the industrial longline fishery, one shark species (longfin mako, *Isurus paucus*) and two (2) ray species (Flapnose ray, *Rhinoptera javanica* and Longhorned mobula, *Mobula eregoodootenkee*) ranked as medium-risk. Based on the IUCN listings, 8 species were listed as critically endangered, two (2) data deficient, 25 endangered, 10 least concern, 16 near threatened and 28 vulnerable. Thus, the overall risk level was medium, with bottom trawlers and artisanal fisheries considered to impact more particularly on coastal elasmobranch species that are sensitive to overfishing, as well as on large pelagic species that use the coastal area during the early stages of their development. The current regional and national regulatory measures used to mitigate fishing mortality are considered. Future research priorities should include studies assessing the elasticity and demographic aspects of all sharks and rays that require urgent attention due to the risk of extirpation. New regulations and improvements to existing legislation in Kenya may have a positive impact in shark populations, which can be examined in future assessments.

Keywords: shark, ray, wedgefish, sawfish, trawl, longline, artisanal

Introduction

Most of the world's catches of sharks are incidentally caught by various types of tuna fishing gear, constituting bycatch that is either discarded at sea (either dead, or just finned) or landed for sale (Carvalho et al., 2011). Bycatch increases the risk of extinction of several species of shark and alters ecosystem functions by removing these top predators (Myers and Baum, 2007). Moreover, bycatch increases the economic risks to the industry because of conservation limits set by the various Regional Fisheries Management Organizations (RFMOs) such as the International Commission for the Conservation of Atlantic Tunas (ICCAT), for example., a cutoff threshold at which fishing should stop, often set at 20% of the unfished equilibrium abundance of relevant species such as the mako shark (Smith et al., 1993).

To develop management options that are both scientifically credible and economically practical regarding the use of ecosystems, decision makers require information on the effects of anthropogenic activities including fishing on ecological processes. With respect to fishing, ~~the~~ ecological risk assessment (ERA) is a suitable framework that provides ecosystem indicators to enable implementation of an ecosystem approach to fisheries management. Ecological risk assessments were first introduced in the 1980s (Hope, 2006) and a variety of different approaches have subsequently been developed (e.g., Scandol et al., 2009). Astles (2008) provided a review of recent developments of ERA in marine fisheries and the elements required to estimate ecological risk. There is a particular need for a simple and transparent way to classify fish stocks and their limits to controllable exploitation in order to guide data collection, scientific assessments, and management advice.

The sustainable management of fisheries resources is a challenging across the world (Sumaila et al., 2016). Fisheries management benefits from accurate stock status estimates to apply harvest control rules and meet management objectives (Mace, 1994; Patrick et al., 2010). Designation of stock status compared to different biological reference points (e.g., maximum sustainable yield) can be adequately made by conventional quantitative stock assessment method, particularly in data- and capacity-rich settings (Carruthers et al., 2016; Fujita et al., 2014). However, large-scale fisheries with target species with high commercial value which are subject to more detailed analyses of their life-history traits, productivity, etc., and are recognized as data-rich stocks. In contrast, the majority of small-scale fisheries, which account for half of the global fishery catches, are data-limited due to less attention given to these fisheries when compared to large-scale industrial fisheries (Costello et al., 2012; FAO, 2020). Consequently, these small-scale fisheries lack the biological and catch data required to estimate stock status using conventional quantitative stock assessment techniques Costello et al., 2012). As a result, the actual status of most global fish stocks from small-scale fisheries remain unknown (Jennings et al., 1999). Such fisheries remain unmanaged or managed with insufficient scientific guidance, leading to suboptimal catch rates and adverse social and economic consequences for those who depend on fishing (Costello et al., 2016). These cases are particularly evident in tropical and subtropical regions where multi-species and multi-gear fisheries exist, and diverse groups of species are often discarded or retained as bycatch of low commercial value (Leadbitter, 2013).

Productivity Susceptibility Analysis (PSA) is a semi-quantitative approach useful as an exploratory or triage tool for prioritizing research, group species with similar vulnerability or risk, and guide decision making (Cortés et al., 2015). Productivity can be described as the capacity of the stock to recover when depleted and susceptibility is the potential for the stock to be negatively impacted by the fishery (Cortés et al., 2015; Arrizabalaga et al. 2011). From estimates of these two components, the vulnerability of the stock can be estimated.

Generally, PSA techniques for bycatch populations are evolving as more studies are completed. Evaluation of vulnerability is generally based on life-history parameters and threats to identify high-risk stocks, then management risk is evaluated by considering factors such as the existence of a stock assessment, management controls, monitoring and compliance (Cortés et al., 2015). However, PSA approaches fall short of providing quantitative management advice, such as appropriate levels of fishing mortality (Cortés et al., 2015).

The most general feature of PSA is that it compares the inherent recovery potential of species once depleted (i.e., productivity attributes) with the attributes of susceptibility (i.e., the impact of the fishery on fish stock) to fishing activities in elucidating overall vulnerability (Stobutzki et al., 2001; Hobday et al., 2011). Since its first use in 2001 for evaluating the risk of an Australian prawn fishery in terms of bycatch stocks, different modifications and improvements have been made to the PSA tool (Faruque and Matsuda, 2021). These include increases in the number of attributes rated, the development of additive methods for calculating the weighted average score for productivity and susceptibility attributes, the inclusion of a five-tier data quality index, and the ability to test a range of alternative approaches for missing data (Patrick et al., 2009). Different scoring approaches, moreover, have been used by scientists to treat the missing data in PSA. One approach is to assign a score representing high risk when the data for a particular attribute is missing, known as the "precautionary or conservative scoring approach" in PSA (Hobday et al., 2011). Most recently, different empirical equations have been used to derive data from correlated life- history attributes when scoring the missing data for a particular attribute (Lucena-Frédou et al., 2017; Lin et al., 2020). For instance, the von Bertalanffy growth coefficient (k; how rapidly a fish reaches its maximum size) is strongly related to fish's maximum age. Long-lived species like sharks and rays have low productivity, and tend to have a high k-value (Froese and Binohlan, 2000). In this way, it is possible to obtain the values for the growth coefficient of fish (if data on the growth coefficient is missing) by using an empirical relationship between the growth coefficient and the maximum age of the fish.

In developing countries, wide latitudinal spread in fishing pressure, a low level of surveillance and year-round fishing in small-scale artisanal fisheries have made it difficult to monitor the status of fisheries (Berg et al., 2002; van der Elst et al., 2012). While different approaches have been used to assess exploitation risk to fish stocks in the WIO, to our knowledge, no risk assessments have been made on elasmobranch stocks to evaluate how well the species would respond to vulnerability and susceptibility attributes of fishing pressure and other exploitative activities.

In coastal Kenya for example, the artisanal fisheries take a significant proportion of sharks and rays either as bycatch or targeted species. The lack of detailed species-specific information has made it difficult to evaluate the effects of fisheries on individual species (Kiilu et al., 2019). It is estimated that about 3,100 artisanal fishing vessels operate in the territorial waters of Kenya (Kenya Marine Frame Survey Report, 2016). About 600 of these vessels target small- and medium-sized pelagic species and reef fishes, with incidental catches of sharks caught mostly in gillnets but the shark bycatch in the artisanal fishery is mainly retained. Considerable quantities of various shark species are also landed as bycatch in the semi-commercial bottom prawn-trawl fishery on the north coast of Kenya (Fulanda et al., 2011; Munga et al., 2014).

Many fish species in Kenya are data-deficient, especially those from fisheries that are considered to be of low economic value. The elasmobranch fisheries in Kenya fall in this category. Most importantly, not only are these fisheries data-limited, but there are limited human resources available for undertaking stock assessment, and would significantly benefit from data-limited methodologies for stock assessments. Furthermore, assessing the vulnerability of stocks to fishing practices in Kenya marine waters is an important factor to 1) identify stocks that should be managed and protected under fishery management plans; 2) group data-poor stocks into relevant management complexes; and 3) develop precautionary harvest control measures.

It is against this backdrop that the present study was undertaken, to assess the vulnerability of sharks and ray species caught in three key fisheries in Kenya waters to PSA risk assessment procedures.

Materials and Methods

Study area description

Collection of landings data was conducted across the whole Kenya coastal waters, including the EEZ extending 200nm. Artisanal fisheries using gillnets, handlines, longlines, and ringnets mainly conduct fishing closer to the coastline at relatively shallower depths, usually extending 5-12nm offshore. The area of interest of trawls was also inshore mainly at the Malindi-Ungwana Bay, while pelagic longlines were far offshore, often close to the international waters. Fieldwork was implemented using local vessels from the small ports of Vanga, Shimoni, Ngomeni and Kipini or their nearby coastal settlements. For all onboard samplings in industrial prawn trawlers and longliners, spatial data of vessels position were collected using onboard GPS location devices and were later used to supplement the distribution range of found species within the country's coastal sea. Locations of the sampling area are shown on Figure 1.

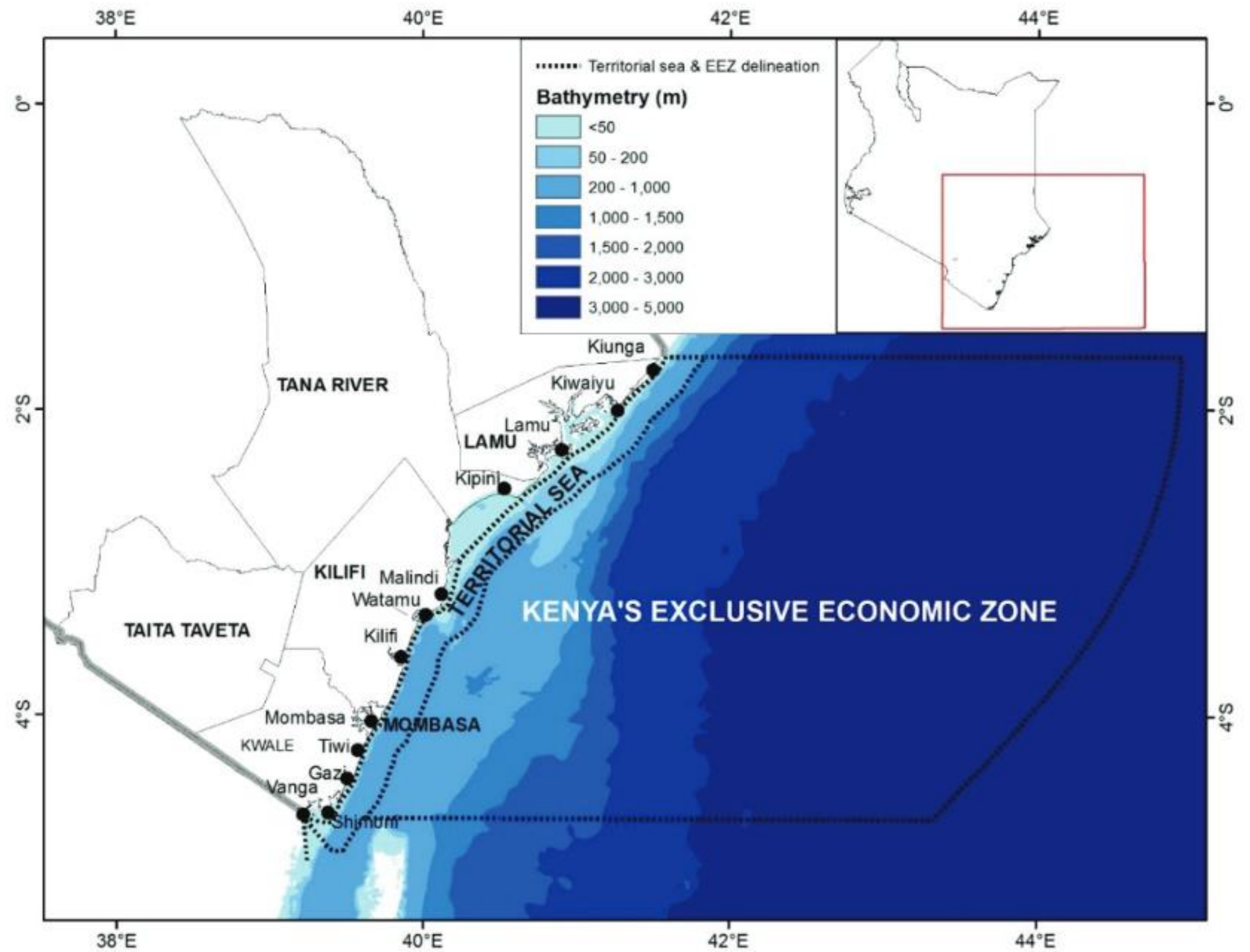

Fig. 1: Map showing Kenya's EEZ and artisanal fishery sampling areas (Vanga, Shimoni, Malindi-Ngomeni, and Kipini), and adjacent coastal settlement areas with overlapping fisheries (Map courtesy: Kenya Marine and Fisheries Research Institute).

Sampling data categories and sources

Sampling was done from four (4) artisanal fish landing sites (Vanga and Shimoni in South Coast of Kenya, and Ngomeni and Kipini in the North Coast), while observer missions were conducted onboard three (3) industrial longline fishing vessels (FV. Shang Jyi, FV. Seamar II and FV. Newfoundland Alert) and 5 industrial prawn trawl fishing vessels (FV. Roberto, FV. Vega, FV. Manyara, FV. Jackpot and FV. Challenger). More data was collected from fishery independent research and training surveys onboard FV. Seamar II, FV. Miss Jane (longliners) and FV. Jonas (a stern trawler).

From these sampling sources, data was continuously collected for 2 years and 6 months by trained data enumerators from September 2019 to March 2022. Each data enumerator recorded details of the fishing vessels and gears used and the number caught., Each specimen was photographed, including close-ups of the head, mouth, eyes vulva/claspers, and body of the specimen.

Photographic identification of each specimen was conducted following protocols described in Ebert et al. (2013) and Last et al. (2018). This procedure was replicated onboard the industrial trawlers and longliners.

All sharks and rays caught were then weighed and measured of their disc widths (for rays) and folk lengths and total lengths as appropriate (since some artisanal fishers do normally cut off the fins of sharks and caudal tails of batoids at the fishing grounds), except protected species caught by industrial fishing vessels and which were only recorded and released. Morphological measurements including total length (TL) for sharks, and TL or disc width (DW) for batoids, weight measurements (in industrial longlines and prawn trawlers, a few of the weights were estimated by the crew whenever the species caught were protected and vulnerable to be hauled in), and degree of calcification of claspers in males and young or eggs in females' uterus (collected in rare occasions during research cruises) were used to identify maturity for each specimen. Sex was determined by assessing the presence of claspers or vulva for each intact specimen.

Specimens that measured below the gender specific length at maturity described for each species in the literature (Ebert et al., 2013; Last et al., 2018; Froese and Pauly, 2020; IUCN Red List, 2022; Pollerspöck and Straube, 2021) were considered immature. Similarly, specimens greater than the gender specific length at maturity and showing hardened claspers and presence of young or eggs were assessed as mature.

Enumerators for artisanal data collection were trained on species identification and equipped with species identification guides. Validation was also conducted routinely to ascertain reliability of the data reported by the enumerators. Owing to the fact that scientific observers had already the requisite training and skills, they were routinely briefed before each observer mission that lasted 2 weeks onboard prawn trawlers and between 20 days to 2 months onboard longliners.

Conservation status

Conservation status of species was determined using the International Union for Conservation of Nature (IUCN) (IUCN Red List, 2022) to assess the impact of fisheries in Kenya on species of concern. Conservation categories defined by IUCN were used and include Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), and Data deficient (DD). Extinct in the Wild (EW) and Extinct (EX) were not considered in the assessment as they were deemed invalid (Table 1).

Table 1: IUCN threat categories to assess extinction risk.

Category	**Definition**
Least concern (LC)	A taxon is Least Concern (LC) when it has been evaluated against the Red List criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened.

Data Deficient (DD)		A taxon is Data Deficient (DD) when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking.
Near threatened (NT)		A taxon is Near Threatened (NT) when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Threatened categories	Vulnerable (VU)	A taxon is Vulnerable (VU) when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable, and it is therefore considered to be facing a high risk of extinction in the wild.
	Endangered (EN)	A taxon is Endangered (EN) when the best available evidence indicates that it meets any of the criteria A to E for Endangered, and it is therefore considered to be facing a very high risk of extinction in the wild.
	Critically endangered (CR)	A taxon is Critically Endangered (CR) when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild.
Extinct in the wild (EW)		A taxon is Extinct In The Wild (EW) when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Extinct (EX)		A taxon is Extinct (EX) when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

Unfortunately, there is a large number of chondrichthyan species lacking information and thus preventing status definitions. Moreover, as some types of anthropogenic pressure like fishing might be poorly reported, the real impact may always be underestimated.

Selection of Productivity (P) and Susceptibility (S) attributes for PSA

Several risk assessment methods were reviewed to determine which approach would be flexible and broadly applicable in the Kenya’s elasmobranch fisheries. A modified version of a productivity and susceptibility analysis (PSA) was selected as the best approach for examining the vulnerability of stocks, owing to its history of use in other fisheries (Milton, 2001; Stobutzki et al., 2001a, 2001b; Braccini et al., 2006; Griffiths et al., 2006; Zhou and Griffiths, 2008), its recommendations by several organizations and working groups as a reasonable approach for determining risk (Hobday et al., 2004; Rosenberg et al., 2007; Smith et al., 2007), and its simplicity.

The PSA was originally developed to classify differences in bycatch sustainability in the Australian prawn fishery (Milton, 2001; Stobutzki et al., 2001b) by evaluating the productivity (p) of bycatch stocks and their susceptibility (s) to the fishery. The values for p and s were determined by providing a score ranging from 1 to 3 for a standardized set of attributes related to each index (i.e., 7 productivity and 6 susceptibility attributes). When data were lacking, scores were based on similar taxa or given the most vulnerable score as a precautionary approach. The scores were then averaged for each index and displayed graphically on an x-y scatter plot. The two-dimensional nature of the PSA leads directly to the calculation of an overall vulnerability score (v) of a species, defined as the Euclidean distance of productivity and susceptibility scores:

$$\nu = \sqrt{\left[(P - X_0)^2 + (S - Y_0)^2 \right]},$$

where x_0 and y_0 are the (x, y) origin coordinates, respectively.

Vulnerability is a measurement of a stock's productivity and its susceptibility to a fishery. Productivity refers to the capacity of the stock to recover rapidly when depleted, whereas susceptibility is the potential for the stock to be impacted by the fishery (Patrick et al., 2010). In general, vulnerability is an important factor to consider when organizing stock complexes, developing buffers between target and limit fishing mortality reference points, and determining which stocks should be man- aged under a fishery management plan (Patrick et al., 2010).

Stocks that receive a low productivity score and a high susceptibility score are considered to be the most vulnerable to overfishing, whereas stocks with a high productivity score and low susceptibility score are considered to be the least vulnerable. Since 2001, the PSA has been modified by others to evaluate habitat, community, and management components of a fishery (Hobday et al. 2004; Rosenburg et al., 2007). In general, these modifications have included expanding the number of attributes for scoring, exploring additive and multiplicative models for combining scores, and examining a variety of alternative treatments for missing data. In the next section we review our application of a PSA to provide a uniform framework for evaluating the wide variety of fish stocks managed within the United States.

A team of experts were assembled to undertake the PSA, and considered 8 productivity attributes (Table 2) and 6 susceptibility attributes (Table 3) in our study.

With the expansion of the PSA to evaluate other management factors (e.g., habitat impacts, ecosystem considerations, management efficacy), the number of attributes that could be considered in a PSA has increased considerably- in some instances to approximately seventy-five (Hobday et al., 2004; Rosenberg et al., 2007). Although ~75 attributes have been recommended, Hobday et al. (2004) noted that the use of more than six attributes per index (e.g., productivity, susceptibility, habitat) does little to improve the accuracy of an assessment.

Many of the productivity attributes are based on Musick's (1999) qualitative extinction risk assessment and the PSA of Stobutzki et al. (2001b). However, the scoring thresholds were modified in many cases to better suit the distribution of life history characteristics observed in Western Indian Ocean (WIO) chondrichthyan stocks. Information on maximum length, maximum age, age-at-maturity, natural mortality, and von Bertalanffy growth coefficient were available from reliable literature for almost all the species considered.

Table 2**.** Productivity and susceptibility attributes and their scoring criteria used to determine the productivity of the selected chondrichthyan stocks from 3 fishery categories in coastal Kenya (adopted from Faruque and Matsuda, 2021).

Thresholds for Biological Parameters					
		Productivity			
	Productivity attribute	**Low Productivity (1)**	**Moderate Productivity (2)**	**High Productivity (3)**	Weight
	r	<0.16	0.16 - 0.5	>0.5	4
	Average maximum age	>25 years	10 - 25 years	<10 years	1
	Maximum size	>150 cm	60 -150 cm	< 60 cm	1
	von Bertalanffy growth coefficient (k)	< 0.15	0.15 - 0.25	> 0.25	2
	Estimated natural mortality (M)	< 0.20	0.20 - 0.40	> 0.40	3
	Measured fecundity or Maximum uterine fecundity	<100 eggs	100 - 20000 eggs	> 20000 eggs	3
		<15 pups	15 - 30 pups	>30 pups	2
	Breeding strategy (BS)	Biennual (every 2 years)	Annual (once a year)	Biannual (twice a year)	1
	Size at first maturity (L_{50})	>100 cm	40 - 100 cm	<40 cm	
	Mean trophic level (MTL)	>3.5	Between 2.5 and 3.5	< 2.5	1
Attribute	**Attribute**	**High Susceptibility (Risk Level 3)**	**Medium Susceptibility (Risk Level 2)**	**Low Susceptibility (Risk Level 1)**	
Availability/ Aereal	Geographical distribution	Restricted to WIO	Spread (Indo-Pacific)	Wide spread (Circumglobal)	2

Encounterability/Vertial	Depth distribution/Behaviour (Artisanal / Aquarium)	Readily accessible to the gear (0-30m)	Accessible to the gear (30 - 60 m)	Limited accessibility to the gear >60m;	2
	Depth distribution/Behaviour (Trawl)	0 - 40m	40 - 60 m	>60m	2
	Depth distribution/Behaviour (Longline)	0 - 60m	60 - 150 m	>150m	2
Selectivity	Relative abundance by number (%) in the catch (gear specific)	>20%	10% - 20%	> 10%	4
Post-Capture Mortality	Probability of survival of individuals of species that escape/are released/discarded AFTER being retained by gear	Mortality high (>60%)	Mortality significant, but <60%	Likely to be alive	4
Desirability	How much effort are fishers likely to deploy to try to capture the specie(s)	Very desirable/ high value. Fishers will go to great lengths to capture it	Medium desirable/ Moderate valuable. Fishers will capture it in their regular activities but will not go to great lengths to capture it	Not desirable / Low value	3
Management strategy (MS)	Management strategy	There is no regulation in effect for the species and no indirect measures	There is no specific regulations for the species, but there are some indirect measures	The species is currently subject to a number of conservation and management measures	3

Data for Attribute Scoring

Data on the productivity attributes (e.g., L_{max}, k, M, measured fecundity, and breeding strategy) were ~~mostly~~ collected from published journal articles, grey literature, and books. We prioritized species-specific data collection from Kenya marine waters or WIO region wherever possible. We also considered the attribute information, especially for information on the MF and BC attributes of some species, for members of the same genus in Bangladesh or the Indian subcontinent, or globally as appropriate, when species-specific data were unavailable (Cope et al., 2011). In cases where information was unavailable for some particular attributes, such as t_{max}, t_{mat} and L_{mat}, of a given species, we considered the empirical relationships (Froese and Binohlan, 2000; Pauly, 1980] between the attributes to calculate the missing attribute values from the values of known attributes of same species based on the assumption that some biological parameters of fish are highly correlated (Jensen, 1980; Reynolds et al., 2001; Roff, 1984). Lin et al. (2020) and Faruque and Matsuda (2020) used similar types of approaches in their assessments. For example, the equation of $t_{max} = 3/k$ (t_{max} = maximum age; k = the von Bertalanffy growth coefficient) was used to estimate t_{max} from the available data on k. We also considered the following equations to calculate the age at first maturity (t_{mat}) and length at first maturity (L_{mat}): $t_{mat} = -\log_e(1 - L_{mat}/L_\infty)/k$ (L_∞ = asymptotic maximum length) and $L_{mat} = L_\infty 10^{(0.8979-0.0782T)}$ (T = water temperature), respectively. Information on the "mean trophic levels" of all assessed elasmobranch stocks was borrowed entirely from the online open-access library FishBase (Froese and Pauly, 2022).

The information on the susceptibility attributes was also collected from published articles, reports, and books. In addition, data on the market demand and selling prices of elasmobranch species, gear selectivity, fishing areas and times, the tendency of fishers to release species back into the water, fishery rules and regulations and their effectiveness, and the fishery's degree of compliance with fishery laws were mainly collected directly from field observations, and in-person interviews with the fishers and fisheries managers.

Results and Discussion

1. Conservation status

Most of the elasmobranch species lacked national or regional IUCN assessments, although global IUCN risk ranks exist. In the present study, from a total of 88 elasmobranch species (sharks, rays, guitarfishes, wedgefishes and sawfishes), 8 were listed as CE, 2 DD, 25 EN, 10 LC, 16 NT and 28 VU (Table 3). Instead, the findings of our PSA (*V* score) were primarily derived for comparison with the global IUCN list. This kind of comparison is also needed to minimize any uncertainty of our PSA outcomes, which eventually increases the confidence in our PSA outcomes. The comparison also supports a better understanding of the relative risks confronted by specific and priority sharks and ray species due to particular fishing activities.

Overall, 69.14% (over two thirds) of the elasmobranch stocks fall in the threatened categories; that is VU, EN and CR. It is also critical to note that 9% of the assessed stocks are in the CE, and therefore considered to be facing an extremely high risk of extinction in the wild. Only 11% are regarded as of less concern (LC), while 2% are considered data deficient (DD). The rest of the species are near threatened (18%)

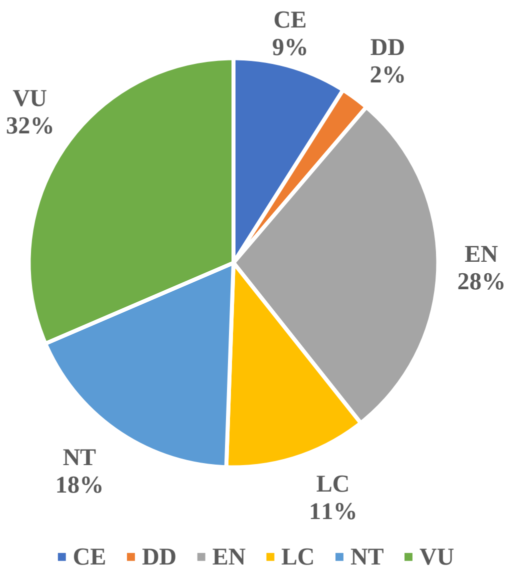

Figure 2: Percentage of vulnerability levels of elasmobranch stocks from coastal Kenya fisheries based on IUCN vulnerability listing.

Table 3: Species of Kenya's Chondrichthyes fauna reported in IUCN threat categories

Species	**Common Name**	**Category**	**IUCN List Category**
Sphyrna lewini	Scalloped hammerhead shark	Shark	CE
Myliobatus aquila	Common eagle ray	Ray	CE
Pseudoginglymostoma brevicaudatum	Short-tail nurse shark	Shark	CE
Rhina ancylostoma	Bowmouth guitarfish	Guitarfish	CE
Rhynchobatus australiae	Bottlenose wedgefish	Wedgefish	CE
Rhynchobatus djiddensis	Giant guitarfish	Guitarfish	CE
Rhynchobatus laevis	Smoothnose wedgefish	Guitarfish	CE
Squatina squatina	Angelshark	Shark	CE
Neotrygon kuhlii	Blue spotted stingray	Ray	DD
Holohalaelurus grennian	Izack catshark	Shark	DD
Rhinoptera javanica	Flapnose ray	Ray	EN
Acroteriobatus leucospilus	Grayspotted guitarfish	Guitarfish	EN
Aetobatus narinari	Whitespotted eagleray	Ray	EN
Alopias pelagicus	Pelagic thresher	Shark	EN
Carcharhinus amblyrhynchos	Blacktail reef shark	Shark	EN
Carcharhinus longimanus	Oceanic whitetip shark	Shark	EN
Carcharhinus plumbeus	Sandbar shark	Shark	EN
Carcharhinus plumbeus	sandbar shark	Shark	EN
Centrophorus sp.	Gulper shark	Shark	EN

Species	Common Name	Category	IUCN List Category
Himantura uarnak	Honeycomb stingray	Ray	EN
Himantura undulata	Leopard whipray	Ray	EN
Isurus oxyrinchus	Shortfin mako	Shark	EN
Isurus paucus	Longfin mako	Shark	EN
Maculabatis gerrardi	Whitespotted whipray	Ray	EN
Manta birostris/ Mobula birostris	Giant manta	Ray	EN
Mobula eregoodootenkee (M. Kohlii)	Longhorned pygmy devil ray	Ray	EN
Mobula kuhlii	Shortfin devilray	Ray	EN
Mobula mobular	Spinetail devilray	Ray	EN
Mustelus manazo	Starspotted smooth-hound	Shark	EN
Mustelus mustelus	Common Smooth hound shark??	Shark	EN
Rhincodon typus	Whale shark	Shark	EN
Rhinoptera javanica	Flapnose ray	Ray	EN
Rhinoptera jayakari	Shorttail cownose rays	Ray	EN
Rostroraja alba	Whiteskate	Skate	EN
Stegostoma tigrinum (also referred to as fasciatum)	Zebra sharks	Shark	EN
Carcharhinus galapagensis	Galapagos shark	Shark	LC
Dasyatis violacea	Pelagic stingray	Ray	LC
Gymnura natalensis	Diamond ray	Ray	LC
Halaelurus lineatus	Lined catshark	Shark	LC
Hypogaleus hyugaensis	Pencil shark	Shark	LC
Neotrygon caeruleopunctata	Bluespotted maskray	Ray	LC
Plesiobatis daviesi	Deepwater stingray	Ray	LC
Raja miraletus	Brown ray	Ray	LC
Squalus megalops	Shortnose spurdog	Shark	LC
Taeniura lymma	Bluespotted sting ray	Ray	LC
Acroteriobatus zanzibarensis	Zanzibar guitarfish	Guitarfish	NT
Carcharhinus altimus	Bignose shark	Shark	NT
Carcharhinus falciformis	Silky shark	Shark	NT
Carcharhinus leucas	Bull shark	Shark	NT
Carcharhinus macloti	Hardnose shark	Shark	NT
Carcharhinus sorrah	Spottail shark	Shark	NT
Dasyatis chrysonota	Blue sting Ray	Ray	NT
Hexanchus nakamurai	Bigeyed sixgill shark	Shark	NT
Loxodon macrorhinus	Sliteye shark	Shark	NT
Maculabatis ambigua	Baraka's whipray	Ray	NT
Mobula japonica	Spinetail mobula	Ray	NT

Species	**Common Name**	**Category**	**IUCN List Category**
Pastincahus sephen	Cowtail stingray	Ray	NT
Prionace glauca	Blue shark	Shark	NT
Raja clavata	Thornback ray	Ray	NT
Scoliodon laticaudus	Spadenose shark	Shark	NT
Squatina africana	African angelshark	Shark	NT
Acroteriobatus annulatus	Lesser sandshark/lesser guitarfish	Guitarfish	VU
Aetobatus ocellatus	Spotted eagle rays	Ray	VU
Alopias superciliosus	Bigeye thresher	Shark	VU
Alopias vulpinus	Common thresher shark	Shark	VU
Bathytoshia lata	Brown stingray	Ray	VU
Carcharhinus albimarginatus	Silvertip shark	Shark	VU
Carcharhinus limbatus	Blacktip shark	Shark	VU
Carcharhinus melanopterus	Blacktip reef shark	Shark	VU
Carcharhinus brachyurus	Copper shark	Shark	VU
Carcharodon carcharias	Great white shark	Shark	VU
Dasyatis pastinaca	Common stingray	Ray	VU
Galeocerdo cuvier	Tiger shark	Shark	VU
Gymnura poecilura	Longtail Butterfly Ray	Ray	VU
Himantura jenkinsii	Jenkin's whipray	Ray	VU
Himantura leoparda	Leopard whipray	Ray	VU
Lamna nasus	Porbeagle shark	Shark	VU
Manta birostris	Giant oceanic manta ray	Ray	VU
Pastinachus ater	Broad cowtail ray	Ray	VU
Pateobatis fai	Pink whipray	Ray	VU
Pateobatis jenkinsii	Cownose ray	Ray	VU
Rhinoptera bonasus	Cownose ray	Ray	VU
Rhizoprionodon acutus	Milk shark	Shark	VU
Sphyrna zygaena	Smooth hammerhead shark	Shark	VU
Squalus acanthias	Picked dogfish	Shark	VU
Taeniurops meyeni	Round ribbontail ray	Ray	VU
Triaenodon obesus	Whitetip reef shark	Shark	VU
Triaenodon obesus	Whitetip reef shark	Shark	VU
Urogymnus granulatus	Mangrove whipray	Ray	VU

2. *PSA Attributes Scoring*

In total, we assessed 48 individual ray species across the four considered artisanal fishery categories (gillnets, handlines, longlines, ringnets, spearguns and traps), and assessed 20 specimens of sharks, five (5) guitarfishes and two (2) wedgefishes and one (1) skate from the artisanal gillnet fishery, 23 sharks and 2 guitarfishes from the handline fishery, and 5 sharks, 1 guitarfish and 1 wedgefish from the ringnet fishery.

From the prawn trawls 23 rays, one (1) skate and 25 shark species were sampled, while from the industrial longline fishery, we sampled 16 shark and 4 ray species

a) Artisanal fisheries

The Bluespotted maskray (*Neotrygon caeruleopunctata*) landed from speargun fishing was assessed as at high risk for that gear, and medium risk for all the other gears that caught the same species (gillnets, handlines and ringnets). Overall, from the artisanal fishery, 14 rays were scored as at medium risk, with 33 rays scoring low. All sharks, guitarfishes and wedgefishes from the artisanal fishery were assessed to be at low risk (Table 4 and 5).

Table 4: Summary of the productivity and susceptibility scoring frequencies and correlations to the overall index or category score for artisanal fisheries ray species caught by gillnets, handlines, artisanal longlines, ringnets, spearguns and traps.

Fishery (Gear)	**Family name**	**Species – Scientific Name**	**Local Name**	**Overall risk value (P&S) (multiplicative)**	**P&S Overall risk category (multiplicative)**
Gillnet	Myliobatidae	*Aetobatus ocellatus*	Ocellated eagle ray	2.317966	Low
	Dasyatidae	*Dasyatis pastinaca*	Common stingray	2.507076	Low
	Gymnuridae	*Gymnura natalensis*	Butterfly ray	2.274076	Low
	Dasyatidae	*Himantura uarnak*	Reticulate whipray	2.540895	Low
	Dasyatidae	*Maculabatis ambigua*	Baraka's whipray	2.656363	Med
	Mobulidae	*Mobula kuhlii*	Shortfin devil ray	2.300189	Low
	Myliobatidae	*Myliobatis aquila*	Common eagle ray	2.484235	Low
	Dasyatidae	*Neotrygon caeruleopunctata*	Bluespotted maskray	3.075311	Med
	Dasyatidae	*Neotrygon kuhlii*	Bluespotted stingray	3.118161	Med
	Dasyatidae	*Pastinachus ater*	Broad cowtail ray	2.358327	Low
	Dasyatidae	*Pateobatis fai*	Pink whipray	2.188806	Low
	Dasyatidae	*Pateobatis jenkinsii*	Jenkin's whipray	2.478919	Low
	Rhinopteridae	*Rhinoptera javanica*	Flapnose ray	2.540895	Low
	Rhinopteridae	*Rhinoptera jayakari*	Oman cownose ray	2.478919	Low
	Dasyatidae	*Taeniura lymma*	Bluespotted ribbontail ray	2.801147	Med
	Dasyatidae	*Taeniurops meyeni*	Round ribbontail ray	2.035937	Low
	Dasyatidae	*Urogymnus granulatus*	Mangrove whipray	2.417939	Low
Handline	Myliobatidae	*Aetobatus ocellatus*	Ocellated eagle ray	2.317966	Low
	Dasyatidae	*Dasyatis pastinaca*	Common stingray	2.507076	Low

	Gymnuridae	*Gymnura natalensis*	Butterfly ray	2.274076	Low
	Dasyatidae	*Himantura uarnak*	Honeycomb stingray	2.540895	Low
	Dasyatidae	*Maculabatis ambigua*	Baraka's whipray	2.507503	Low
	Mobulidae	*Mobula japonica*	Spinetail mobula	2.312197	Low
	Mobulidae	*Mobula mobular*	Devil fish	2.416813	Low
	Myliobatidae	*Myliobatis aquila*	Common eagle ray	2.484235	Low
	Dasyatidae	*Neotrygon caeruleopunctata*	Bluespotted maskray	3.075311	Med
	Dasyatidae	*Neotrygon kuhlii*	Bluespotted stingray	3.118161	Med
	Dasyatidae	*Pastinachus sephen*	Cowtail stingray	2.460948	Low
	Dasyatidae	*Pateobatis fai*	Pink whipray	2.188806	Low
	Rhinopteridae	*Rhinoptera javanica*	Flapnose ray	2.540895	Low
	Dasyatidae	*Taeniura lymma*	Bluespotted ribbontail ray	2.801147	Med
Longline	Myliobatidae	*Aetobatus ocellatus*	Ocellated eagle ray	2.317966	Low
	Dasyatidae	*Bathytoshia lata*	Broad stingray	2.114138	Low
	Dasyatidae	*Dasyatis pastinaca*	Common stingray	2.507076	Low
	Dasyatidae	*Himantura leoparda*	Leopard whipray	2.709425	Med
	Dasyatidae	*Himantura uarnak*	Baraks's whipray	2.621634	Low
	Dasyatidae	*Maculabatis ambigua*	Bluespotted stingray	2.507503	Low
	Dasyatidae	*Neotrygon kuhlii*	Bluespotted stingray	3.118161	Med
	Rhinopteridae	*Rhinoptera javanica*	Flapnose ray	2.540895	Low
Ringnet	Myliobatidae	*Aetobatus ocellatus*	Baraka's whipray	2.317966	Low
	Dasyatidae	*Neotrygon caeruleopunctata*	Bluespotted maskray	2.656363	Med
	Dasyatidae	*Neotrygon caeruleopunctata*	Bluespotted maskray	3.075311	Med
	Dasyatidae	*Pateobatis jenkinsii*	Jenkin's whipray	2.478919	Low
	Rhinopteridae	*Rhinoptera jayakari*	Oman cownose ray	2.598991	Low
	Dasyatidae	*Taeniura lymma*	Bluespotted ribbontail ray	2.978753	Med
Speargun	Dasyatidae	*Neotrygon caeruleopunctata*	Bluespotted maskray	3.237913	High
	Dasyatidae	*Taeniura lymma*	Bluespotted ribbontail ray	2.978753	Med
Trap	Dasyatidae	*Taeniura lymma*	Bluespotted ribbontail ray	2.978753	Med

Table 5: Summary of the productivity and susceptibility scoring frequencies and correlations to the overall index or category score for artisanal fisheries sharks, guitarfishes and wedgefishes caught by gillnets, handlines and ringnets.

Fishery (Gear)	**Family**	**Species – Scientific Name**	**Local Name**	**Overall risk value (P&S) (multiplicative)**	**P&S Overall risk category (multiplicative)**
Gillnet	Rhinobatidae	*Acroteriobatus annulatus*	Lesser guitarfish	2.39716	Low
	Rhinobatidae	*Acroteriobatus zanzibarensis*	Zanzibar guitarfish	2.375015	Low
	Rhinobatidae	*Acroteriobatus leucospilus*	Grayspotted guitarfish	2.375015	Low
	Carcharinidae	*Carcharhinus albimarginatus*	Silver-tip	1.924037	Low
	Carcharinidae	*Carcharhinus brevipinna*	Spinner shark	1.74563	Low

	Carcharinidae	*Carcharhinus amblyrhynchos*	Grey-reef shark	1.987576	Low
	Carcharinidae	*Carcharhinus falciformis*	Silky shark	1.74563	Low
	Carcharinidae	*Carcharhinus humani*	Human's whale shark	1.74563	Low
	Carcharinidae	*Carcharhinus leucus*	Bull shark	2.015263	Low
	Carcharinidae	*Carcharhinus limbatus*	Blacktip shark	1.923729	Low
	Carcharinidae	*Carcharhinus macloti*	Hardnose shark	2.183297	Low
	Carcharinidae	*Carcharhinus melanopterus*	Blacktip reef shark	1.987576	Low
	Carcharinidae	*Carcharhinus sorrah*	Spot-tail shark	2.456541	Low
	Carcharinidae	*Galeocerdo cuvier*	Tiger shark	2.278175	Low
	Triakidae	*Mustelus manazo*	Starspotted smooth-hound	2.274051	Low
	Triakidae	*Mustelus mustelus*	Common smooth hound shark	2.051948	Low
	Ginglymostomatidae	*Pseudoginglymostoma brevicaudatum*	Short-tail nurse shark	1.842325	Low
	Rhinidae	*Rhina ancylostoma*	Bowmouth guitarfish	2.164369	Low
	Carcharinidae	*Rhizoprionodon acutus*	Milk shark	1.842325	Low
	Rhinidae	*Rhynchobatos australiae*	Bottlenose wedgefish	2.252166	Low
	Rhinidae	*Rhynchobatus djiddensis*	Giant guitarfish	2.284352	Low
	Rhynchobatidae	*Rhynchobatos laevis*	Smoothnose wedgefish	1.898294	Low
	Rhincodontidae	*Rhincodon typus*	whale shark	2.082838	Low
	Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead shark	2.197893	Low
	Sphyrnidae	*Sphyrna zygaena*	Smooth hammerhead shark;	1.987576	Low
	Squantidae	*Squatina africana*	African angelshark	2.480101	Low
	Carcharinidae	*Triaenodon obesus*	Whitetip reef shark	2.086859	Low
Handline	Rhinobatidae	*Acroteriobatus zanzibarensis*	Zanzibar guitarfish	2.375015	Low
	Alopiidae	*Alopias pelagicus*	Pelagic thresher	1.724114	Low
	Alopiidae	*Alopias superciliosus*	Bigeye thresher	1.512131	Low
	Carcharinidae	*Carcharhinus albimarginatus*	Silver-tip	1.924037	Low
	Carcharinidae	*Carcharhinus amblyrhynchos*	Grey-reef shark	1.987576	Low
	Carcharinidae	*Carcharhinus falciformis*	Silky shark	1.74563	Low
	Carcharinidae	*Carcharhinus humani*	Human whaler shark	1.74563	Low
	Carcharinidae	*Carcharhinus leucus*	Bull shark	2.015263	Low
	Carcharinidae	*Carcharhinus limbatus*	Blacktip shark	1.923729	Low
	Carcharinidae	*Carcharhinus macloti*	Hardnose shark	2.183297	Low
	Carcharinidae	*Carcharhinus melanopterus*	Blacktip reef shark	1.987576	Low
	Carcharinidae	*Carcharhinus plumbeus*	Sand-bar shark	1.74563	Low
	Carcharinidae	*Carcharhinus sorrah*	Spot-tail shark	2.456541	Low
	Carcharinidae	*Centrophorus sp.*	Gulper shark	1.724114	Low
	Carcharinidae	*Galeocerdo cuvier*	Tiger shark	2.278175	Low
	Hexanchidae	*Hexanchus nakamurai*	Bigeyed sixgill shark	1.946509	Low
	Carcharinidae	*Loxodon macrorhinus*	Slit eye shark	2.288268	Low
	Triakidae	*Mustelus manazo*	Starspotted smooth-hound	2.274051	Low

	Triakidae	*Mustelus mustelus*	Common Smooth hound shark	2.051948	Low
	Carcharinidae	*Rhizoprionodon acutus*	Milk shark	1.842325	Low
	Rhinidae	*Rhinobatos holcorhynchus*	Slender guitarfish	2.117497	Low
	Carcharinidae	*Scolliodon laticadus*	Spadenose shark	2.375015	Low
	Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead shark	2.197893	Low
	Squantidae	*Squatina africana*	African angelshark	2.480101	Low
	Carcharinidae	*Triaenodon obesus*	Whitetip reef shark	2.086859	Low
Ringnet	Rhinobatidae	*Acroteriobatus zanzibarensis*	Zanzibar guitarfish	2.375015	Low
	Carcharinidae	*Carcharhinus humani*	Human's whaler shark	1.74563	Low
	Carcharinidae	*Carcharhinus sorrah*	Spot-tail shark	2.456541	Low
	Carcharinidae	*Rhizoprionodon acutus*	Milk shark	1.842325	Low
	Rhinidae	*Rhynchobatos australiae*	Bottlenose wedgefish	2.252166	Low
	Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead shark	2.197893	Low
	Carcharinidae	*Triaenodon obesus*	Whitetip reef shark	2.086859	Low

b) Trawl fisheries

In the trawl fishery, one (1) shark species, the Grinning izak catshark (*Holohalaelurus grennian*) was scored as at high risk, while three (3) ray species (*Himantura jenkinsii, Raja miraletus,* and *Taeniura lymma*) and eight (8) shark species (*Scoliodon laticaudus, Squatina squatina, Loxodon macrorhinus, Halaelurus lineatus, Mustelus mustelus, Carcarhinus melanopterus, Pseudoginglymostoma brevicaudatum* and *Squatina africana*) were assessed to be at medium risk. (Table 6 and 7).

Table 6: Summary of the productivity and susceptibility scoring frequencies and correlations to the overall index or category score for shark species caught by the industrial prawn trawl fishery.

Family	**Species – Scientific Name**	**Local Name**	**Overall risk value (P&S) (multiplicative)**	**P&S Overall risk category (multiplicative)**
Carcharinidae	*Charcharinus limbatus*	Blacktip shark	2.329736	Low
Rhincodontidae	*Rhoncodon typus*	Whale shark	2.348397	Low
Carcharinidae	*Scoliodon laticaudus*	Spadenose shark	2.981175	Med
Squalidae	*Squalus megalops*	Shortnose spurdog	2.225291	Low
Squalidae	*Squalus acanthias*	Picked dogfish	2.329736	Low
Squatinidae	*Squatina squatina*	African angelshark	2.748468	Med
Pentanchidae	*Halaelurus lineatus*	Lined catshark	2.805729	Med
Pentanchidae	*Holohalaelurus grennian*	Grinning izak catshark	3.343838	High
Carcharinidae	*Loxodon macrorhinus*	Sliteye shark	2.750492	Med
Triakidae	*Mustelus mustelus*	Smooth-hound	2.640216	Med
Carcharinidae	*Carcharhinus albimarginatus*	Silvertip shark	2.130442	Low
Sphyrnidae	*Sphyrna zygaena*	Smooth-hammerhead	2.446874	Low
Carcharinidae	*Carcharhinus amblyrhinchos*	Grey reef shark	2.411474	Low

Carcharinidae	*Carcharhinus leucas*	Bull shark	2.446874	Low
Carcharinidae	*Carcharhinus falciformis*	Silky shark	1.941478	Low
Carcharinidae	*Carcharhinus macloti*	Hardnose shark	2.557104	Low
Carcharinidae	*Carcarhinus melanopterus*	Blacktip reef shark	2.679786	Med
Triakidae	*Mustelus mosis*	Arabian smooth-hound	2.607594	Low
Lamnidae	*Carcharodon carcharias*	Great white shark	2.043935	Low
Galeocerdonidae	*Galeocerdo cuvier*	Tiger shark	2.557104	Low
Ginglymostomatidae	*Pseudoginglymostoma brevicaudatum*	Shorttail nurse shark	2.837172	Med
Carcharhinidae	*Sphyrna lewini*	Scalloped hammerhead	2.348397	Low
Squatinidae	*Squatina africana*	African angelshark	3.102531	Med
Stegostomatidae	*Stegostoma tigrinum*	Zebra shark	2.508459	Low
Carcharhinidae	*Triaenodon obesus*	Whitetip reef shark	2.356708	Low

Table 7: Summary of the productivity and susceptibility scoring frequencies and correlations to the overall index or category score for ray species caught by the industrial prawn trawl fishery.

Family	**Species – Scientific Name**	**Local Name**	**Overall risk value (P&S) (multiplicative)**	**P&S Overall risk category (multiplicative)**
Aetobatidae	*Aetobatus narinari*	Whitespotted eagleray	1.955876	Low
Gymnuridae	*Gymnura natalensis*	Diamond ray	2.073083	Low
Gymnuridae	*Gymnura poecilura*	Longtail Butterfly Ray	2.329736	Low
Dasyatidae	*Himantura jenkinsii*	Jenkin's whipray	2.862335	Med
Dasyatidae	*Himantura leoparda*	Leopard whipray	2.340875	Low
Dasyatidae	*Himantura uarnak*	Honeycomb stingray	2.340875	Low
Dasyatidae	*Himantura undulata*	Leopard whipray	2.311489	Low
Dasyatidae	*Maculabatis ambigua*	Baraka's whipray	2.329736	Low
Dasyatidae	*Maculabatis gerrardi*	Whitespotted whipray	2.518528	Low
Mobulidae	*Manta birostris/Mobula birostris*	Giant manta	1.941478	Low
Mobulidae	*Mobula japonica*	Spinetail mobula	2.440379	Low
Mobulidae	*Mobula kuhlii*	Shortfin devilray	2.518528	Low
Mobulidae	*Mobula mobular*	Spinetail devilray	1.955876	Low
Myliobatidae	*Myliobatus aquila*	Common eagle ray	2.225291	Low
Plesiobatidae	*Plesiobatis daviesi*	Deep-water stingray	1.846289	Low
Rajidae	*Raja clavata*	Thornback ray	2.596559	Low
Rajidae	*Raja miraletus*	Brown ray	2.737173	Med
Rajidae	*Rostroraja alba*	Whiteskate	2.225291	Low
Dasyatidae	*Dasyatis chrysonota*	Blue sting Ray	2.27728	Low
Dasyatidae	*Dasyatis pastinaca*	Common stingray	2.073083	Low
Dasyatidae	*Neotrygon kuhlii*	Blue spotted stingray	2.459202	Low
Dasyatidae	*Pastincahus sephen*	Cowtail stingray	2.538299	Low
Dasyatidae	*Taeniura lymma*	Bluespotted sting rays	2.679118	Med
Dasyatidae	*Taeniurops meyeni*	Round ribbontail ray	2.015696	Low

c) *Industrial longline fishery*

The longline fishery recorded one (1) shark species (*Isurus paucus*) and two (2) ray species (*Rhinoptera javanica* and *Mobula eregoodootenkee*) in the medium risk level (Table 8).

Table 8: Summary of the productivity and susceptibility scoring frequencies and correlations to the overall index or category score for sharks and rays species caught by the industrial longline fishery.

Family	**Species – Scientific Name**	**Local Name**	**Overall risk value (P&S) (multiplicative)**	**P&S Overall risk category (multiplicative)**
Alopiidae	*Alopias superciliosus*	Bigeye thresher	2.410519	Low
Lamnidae	*Lamna nasus*	Porbeagle shark	1.802776	Low
Lamnidae	*Isurus paucus*	Longfin mako	2.672814	Med
Carcharhinidae	*Sphyrna lewini*	Scalloped hammerhead	2.312012	Low
Carcharhinidae	*Carcharhinus plumbeus*	Sandbar shark	2.312012	Low
Carcharhinidae	*Carcharhinus longimanus*	Oceanic white shark	2.392906	Low
Lamnidae	*Isurus oxyrhichus*	Shortfin mako	1.952076	Low
Carcharhinidae	*Prionace glauca*	Blue shark	2.339596	Low
Carcharhinidae	*Carcharhinus albimarginatus*	Silvertip shark	1.952076	Low
Galeocerdonidae	*Galeocerdo cuvier*	Tiger shark	2.410519	Low
Lamnidae	*Carcharodon carcharias*	Great white shark	1.652892	Low
Carcharhinidae	*Carcharhinus falciformis*	Silky shark	2.017899	Low
Carcharhinidae	*Carcharhinus galapagensis*	Galapagos shark	2.151375	Low
Alopiidae	*Alopias vulpinus*	Common thresher shark	2.357756	Low
Carcharhinidae	*Carcharhinus brachyurus*	Copper shark	1.536591	Low
Carcharhinidae	*Carcharhinus melanopterus*	Blacktip reef shark	2.548066	Low
Dsyatidae	*Pteroplatytrygon violacea*	Pelagic stingray	2.489623	Low
Mobulidae	*Mobula birostris*	Giant manta	2.141219	Low
Rhinopteridae	*Rhinoptera javanica*	Flapnose ray	2.89161	Med
Mobulidae	*Mobula eregoodootenkee*	Longhorned mobula	2.798862	Med

Recommendation and conclusion

In response to rising concerns on the impacts of target fisheries on bycatches and associated species, fishery scientists have sought to develop comprehensive risk assessment and management tools for all exploited fishery stocks. PSA is one such tool that can include a large number of exploited stocks in an assessment framework to evaluate the relative risk among species interacting with particular gear types.

In the present study, we calculated the vulnerability for the 94 Chondrichthyan stocks from coastal Kenya marine fishery. Finally, our PSA outcomes were compared with the levels of protection accorded to the species at national and global levels (IUCN). This is information that can significantly contribute to policy development to protect sharks and rays in Kenya marine waters.

While the PSA results are less precise than those obtained from fully quantitative stock assessments, it is noteworthy that when comprehensive data on stock abundance, catch levels, or other conventional fisheries indicators are lacking, PSA offers a helpful starting point for identifying the relative risk of a species due to fishing, thus prioritizing data collections, future research needs, and management activities.

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