Interactions between coastal fisheries and Critically Endangered scalloped hammerhead sharks in the Western Indian Ocean

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Abstract

Scalloped hammerhead sharks *Sphyrna lewini* are commonly landed in coastal fisheries across the Western Indian Ocean, often among the most frequently landed shark species. They are retained both for their meat and their high-value fins (among the highest globally for any shark species). Given their Critically Endangered conservation status, large body size, slow growth and late attainment of sexual maturity, the species is not resilient to fishing pressure. The species' coastal and pelagic ecology as well as its broad global distribution heighten its risk through exposure to offshore industrial and small-scale coastal fisheries. While *S. lewini* is prohibited in the jurisdictions of certain Regional Fisheries Management Organizations (RFMOs), such as International Commission for the Conservation of Atlantic Tunas (ICCAT), the species is not prohibited from capture by the Indian Ocean Tuna Commission (IOTC) and coastal fishery landings and impacts have generally not been considered in most RFMO management considerations. *Sphyrna lewini* is also not one of the species for which species-level catch recording is obligatory, under the IOTC's Resolution 15/01 (On the recording of catch and effort data by fishing vessels in the IOTC area of competence), leaving limited species-level catch data for this species in the Western Indian Ocean. This paper presents information on landings of *S. lewini* across several WIO states, including numbers and sizes landed, as well as the most impactful fishing gears. *Sphyrna lewini* landed in artisanal fisheries throughout the WIO are predominantly juveniles (neonates and young-of-the-year individuals), suggesting that coastal fisheries (at least in some areas) overlap with *S. lewini* nursery areas. Continued fishing pressure in these habitats may lead to growth overfishing of the species, and it is possible that this may already be happening. Gillnets were identified as the primary gear type impacting *S. lewini* across jurisdictions, underscoring their significant negative effect on this (and many other) species.

Keywords

Artisanal fishery, elasmobranch, Sphyrnidae, scalloped hammerhead, Kenya, Mozambique

Introduction

The scalloped hammerhead *Sphyrna lewini* is a circumglobal species occurring in coastal-pelagic warm-temperate and tropical seas (Ebert et al. 2021). It attains a maximum size of 370–430 cm total length (TL), with males maturing at 140–198 cm TL and females at 200–250 cm TL, and exhibits a biennial reproductive cycle with litter sizes of 12–41 pups (Ebert et al. 2021). Although recorded at depths exceeding 1,000 m, the species is most commonly found in waters shallower than 275 m (Moore and Gates 2015), with pregnant females and juveniles predominantly occupying coastal habitats (Bass et al. 1975). This habitat use exposes the species to interaction with a wide range of fisheries, from small-scale and artisanal operations in coastal zones (where juveniles are particularly vulnerable) to industrial longline, gillnet, and purse seine fleets operating further offshore but still within the species' primary depth range. As a result, *S. lewini* is exposed to multiple gear types and fishing sectors throughout its life history.

These ecological traits, including slow growth, late maturity, and relatively low fecundity, confer high intrinsic vulnerability to exploitation. Sustained fishing pressure across its range has led to global population declines exceeding 80%, resulting in its classification as Critically Endangered on the IUCN Red List of Threatened Species (Rigby et al. 2019). This vulnerability is particularly pronounced in the Western Indian Ocean (WIO), a region recognised as a global hotspot for chondrichthyan diversity and endemism, with more than 220 species recorded (Bennett et al. 2022). Fisheries in the WIO are widespread and diverse, encompassing artisanal, commercial, and industrial sectors, as well as foreign fleets and illegal, unreported, and unregulated (IUU) fishing activities. As a result, chondrichthyans are subjected to substantial fishing pressure, both as bycatch and as targeted species driven by demand for meat and the high value of fins in international trade (Bennett et al. 2022).

In Kenya, marine fisheries are predominantly small-scale, with artisanal and subsistence sectors contributing over 90% of total landings (Kiszka and van der Elst 2015). These fisheries operate mainly in shallow coastal waters, are widely distributed, and utilise diverse gear types to target a broad range of species (Samoilys et al. 2017). Increasing fishing effort has resulted in unsustainable exploitation levels and growing pressure on marine resources, including chondrichthyans (Le Manach et al. 2015; Samoilys et al. 2017; Kiilu et al. 2019). Additional pressure arises from a semi-industrial shrimp trawl fishery in Ungwana Bay, a major source of chondrichthyan bycatch, as well as semi-commercial longline fisheries operating off Mombasa and targeting pelagic sharks such as *Alopias* spp. and *Isurus* spp. (Kiilu and Ndegwa 2013; Ndegwa et al. 2020).

Similarly, fishing pressure in Mozambique is substantial, with approximately 60% of the population dependent on fisheries for livelihoods (Kiszka and van der Elst 2015). The sector is dominated by artisanal and subsistence fisheries, which contribute between 75% and 88% of total marine landings, exceeding 100,000 tonnes annually (IDPPE 2013; Doherty et al. 2015; UNCTAD 2017). These fisheries operate primarily in nearshore waters along the coastline and employ a wide range of gear types (Jacquet et al. 2010; Doherty et al. 2015; Everett et al. 2017). Semi-industrial and industrial fleets, along with foreign and IUU fishing activities, further contribute to overall fishing effort (UNCTAD 2017). While industrial fisheries target species such as shrimp and large pelagics, artisanal fisheries exploit a diverse assemblage including small pelagics, demersal species, and sharks. Chondrichthyans are therefore captured across all sectors, often as both target and bycatch species.

Aim

Given the overlap between *S. lewini* habitat use and coastal fishing activities, there is a need to better understand the extent of its exploitation in small-scale fisheries. To address this, we summarise artisanal fishery landings of *S. lewini* in Kenya and Mozambique, supplemented by anecdotal observations from Madagascar, and draw on published data from other WIO countries.

Methods

The Wildlife Conservation Society (WCS) has conducted surveys at selected landing sites and fish markets in Kenya, while the Oceanographic Institute of Mozambique (InOM), in partnership with WCS, World Wide Fund for Nature (WWF), Universidade Lúrio, and Eduardo Mondlane University has conducted similar surveys in Mozambique, to record sharks and rays landed in the small-scale coastal fisheries.

Data were initially recorded on paper, with photographs taken to support species identification. Data collection later transitioned to mobile-based platforms, first using Atlan Collect and subsequently KoboCollect. These applications guided data collectors through standardized questions and required the capture of specific photographs to facilitate accurate identification. Accordingly, all sharks and rays observed during surveys were recorded, measured where possible (i.e. when individuals were whole), photographed for species verification, and the gear type used to capture each individual was documented.

In Kenya, a total of 4,428 survey days took place across eight sites in five coastal counties (Lamu, Tana River, Kilifi, Mombasa, and Kwale – Fig. 1) between October 2018 and March 2024. In Mozambique, sharks and rays were landed on 383 survey days across 8 landing sites (Fig. 1) between November 2018 and July 2024. No information is available for Mozambique on survey days on which sharks were not landed, preventing estimates of catch-per-unit-effort.

Figure 1. Map of East Africa depicting Mozambique and Kenya. Black dots indicate shark and ray survey site locations in each country.

Surveys were conducted on three randomly selected days per week in Kenya, whereas in Mozambique sampling was conducted opportunistically due to logistical and operational constraints affecting survey scheduling. Monitoring in Kenya was conducted continuously at each site throughout the period, other than unavoidable interruptions.

To describe the diversity of the elasmobranch catch, the total number of individuals caught was summed for each species, and the percentage of each species in the overall catch was calculated.

Finally, data on elasmobranch landings in industrial and artisanal fisheries were also obtained from submissions to the Indian Ocean Tuna Commission (IOTC 2026).

Results

Species composition

Between November 2018 and July 2024, surveys recorded a total of 2,206 elasmobranchs landed in artisanal fisheries across Mozambique, on 383 sampling days, comprising 1,739 sharks and 467 rays. At least 35 species were identified (15 shark and 20 ray species), indicating relatively high elasmobranch species richness within artisanal catches.

Hammerhead sharks (family Sphyrnidae) dominated shark landings, accounting for 1,007 individuals (58% of all sharks recorded). Of these, 836 were positively identified as scalloped hammerhead sharks *Sphyrna lewini*, representing 83% of hammerheads, 48% of all sharks, and 38% of all elasmobranchs recorded. This indicates that *S. lewini* was the most frequently landed species across the surveyed sites. The remaining 171 hammerheads were not identified to species level; however, as no other hammerhead species were confirmed during the surveys, it is likely that most, if not all, of these individuals were also *S. lewini*.

In Kenya, a total of 2,305 sharks and rays were recorded across monitored landing sites and markets, representing at least 33 shark species and 23 ray species. Among these, *S. lewini* was the fifth most frequently landed species overall, and the most commonly landed shark species, with 162 individuals recorded during the survey period. This accounted for 7% of all elasmobranchs and 17% of all sharks recorded.

Table 1. Number of landing sites monitored per year throughout Kenya, including the total number of possible survey days per year and the average number of scalloped hammerheads *Sphyrna lewini* landed per year.

Year	Sites monitored	Days in year	Possible survey days	*S. lewini*/year
2018	5	365	1,825	66.8
2019	5	365	1,825	66.8
2020	8	365	2,920	106.8
2021	8	365	2,920	106.8
2022	8	365	2,920	106.8
2023	8	365	2,920	106.8
2024	8	365	2,920	106.8
Mean/year				95.4
Total			18,250	667.7

Catch-per-unit-effort and extrapolated total catch

To estimate the total number of *S. lewini* landed at monitored survey sites in Kenya (including non-survey days), we extrapolated mean daily catch rates from recorded survey effort (Table 1). A total of 162 individuals were recorded over 4,428 survey days, yielding a mean catch rate of 0.03659 sharks per survey day. Extrapolated across all possible survey days (18,250), this corresponds to an estimated 668 individuals landed, or a mean of 95.4 individuals per year. These estimates represent landings at monitored sites only, and do not include any potential landings at other Kenyan landing sites.

In Mozambique, survey data were collected only on days on which a shark/ray of any species were recorded. This totalled 383 days on which an elasmobranch was recorded, of which at least one *S. lewini* was recorded on 119 (31%) of those days. Given the 836 *S. lewini* landed, this works out to a mean of 7.03 *S. lewini* per day on which this species was landed. However, the total catch over this period cannot be extrapolated, due to a lack of data on survey dates with zero shark landings.

Data obtained from the Indian Ocean Tuna Commission (IOTC) indicate that between 2015 and 2024, Kenya and Mozambique landed a combined total of 7,855.29 mt and 19,606.55 mt of sharks and rays, respectively, across both industrial and artisanal fisheries (IOTC 2026). In both countries, artisanal fisheries accounted for the majority of these landings, contributing 7,187.46 mt in Kenya and 19,419.05 mt in Mozambique, substantially exceeding industrial catches. *Sphyrna lewini* were reported in landings from both countries, but exclusively within the artisanal sector. They comprised 668.01 mt of total elasmobranch landings in Kenya (9.3% of artisanal landings) and 2,829.81 mt in Mozambique (14.6% of artisanal landings). Crudely applying the proportions of elasmobranch landings comprising *S. lewini,* from the species-level landings data reported in this document (38% of all elasmobranchs reported in Mozambique and 17% in Kenya), to the total elasmobranch landings reported to the IOTC (2,828 mt in Mozambique and 668 mt in Kenya), suggests 1,075 mt of *S. lewini* landed in Mozambique and 46.7 mt in Kenya, from 2015 to 2024.

Overall, IOTC landings reported from the Western Indian Ocean total at least 3,736 mt of *S. lewini* between 2015 and 2024, with the vast majority (94% landed in the most recent three years (2022-2024) of the dataset.

Size structure and sex ratios

In Mozambique, sex information is available for 623 of the *S. lewini* landed, comprising 331 females and 292 males with a male:female sex ratio of 1:1.13. In Kenya, sex information is available for 161 individuals (99% of all *S. lewini* recorded), comprising 59 females and 102 males, revealing a skewed sex ratio of 1:1.7 (female:male), indicating that males were more than one-and-a-half times more abundant than females in the landings.

Length data were available for 161 and 648 *S. lewini* in Kenya and Mozambique, respectively, with size-frequency distributions indicating a strong dominance of juveniles in artisanal fishery landings in both countries (Fig. 2). In Mozambique, individuals ranged from 36 to 360 cm total length (TL), although the catch was overwhelmingly composed of smaller size classes (Fig. 2a). The smallest individuals (40–60 cm TL) correspond to neonates (dashed arrow), with approximately equal sex ratios, indicating the presence of recently born individuals in the catch. Slightly larger young-of-the-year (YOY) individuals (black arrow) were also well represented, again

with near-equal sex ratios. Overall, 71% of measured individuals (n = 461) were landed at sizes indicative of being one year old or younger. Few individuals in the intermediate size classes (roughly 80–200 cm TL) were recorded, and only two individuals (one male and one female) exceeding 200 cm TL, both of which were larger than the size at sexual maturity.

In Kenya, *S. lewini* exhibited a much narrower size range, from 47 to 90 cm TL (Fig. 2b), further emphasising the dominance of early life stages in the catch. Neonates (40–60 cm TL) were particularly prevalent, with a female-biased sex ratio (1:1.8 females:males), while YOY individuals were present but less well represented (1:1.5 females:males). Across larger size classes (>80 cm TL), just three individuals were recorded, two males and one female and all less than 100 cm TL. No larger individuals were recorded, indicating that all *S. lewini* recorded were well below the published sizes at maturity (~215 cm TL for males, blue arrow, and ~245 cm TL for females, green arrow). Overall in Kenya, 87% of the individuals landed were neonates and 11% were YOY; 100% were not yet mature. Together, these patterns indicate that artisanal fisheries in both countries primarily interact with juvenile *S. lewini*, particularly neonates and YOY individuals.

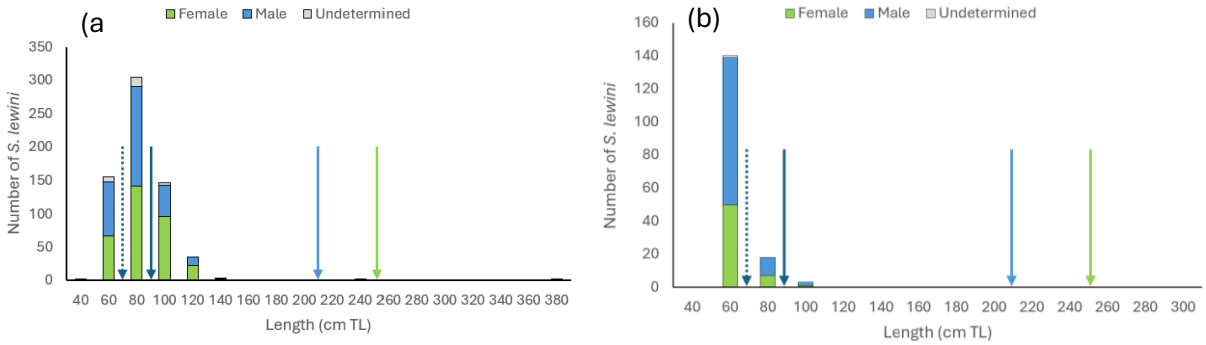

Figure 2. Size frequency distributions for *Sphyrna lewini* landed in artisanal fisheries in (a) Mozambique and (b) Kenya, including published sizes for neonates (dashed arrow), young-of-the year (black arrow), first attainment of sexual maturity for males (blue arrow) and females (green arrow).

Impacts of gear type on landed *Sphyrna lewini*

In Mozambique, of the 836 *S. lewini* landed, gear types were recorded for 293 individuals, of which 206 individuals (70%) were caught with bottomset gillnets, 62 (21%) with surface gillnets, 14 (5%) with handlines, 8 (3%) with beach seines and 3 (1%) with longlines (Fig. 3a). The dominance of gillnets (91% for bottomset and surface gillnets combined) highlights their central role in *S. lewini* capture. Bottom-set gillnets, in particular, are likely deployed in shallow coastal areas, including nursery habitats, which explains the high capture rates of neonates and small juveniles.

In Kenya, gear information was available for 161 of the 162 *S. lewini* individuals recorded. Of these, 65 individuals (40%) were caught with “shark nets” (gillnets with mesh size >6 inches), 46 individuals (29%) with drift nets, 42 (26%) with gillnets (nets with mesh size of 2.5-3 inches), and the remaining 8 individuals (5%) were caught with longlines, handlines and ring nets (Fig. 3b). Overall, gillnets (all types of gillnets combined) were responsible for the capture of 153 (95%) of the recorded *S. lewini*, highlighting the impact of gillnets on this species.

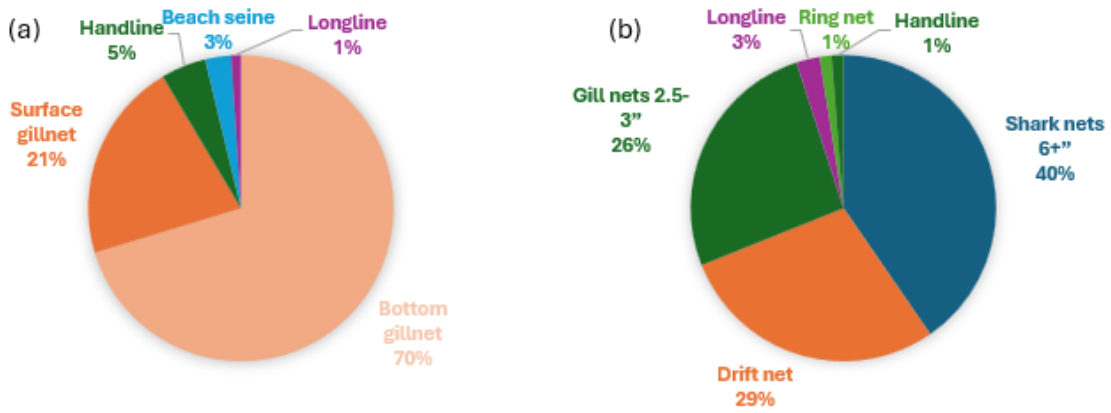

Figure 3. Proportions of scalloped hammerheads *Sphyrna lewini* landed in artisanal fisheries in (a) Mozambique and (b) Kenya, disaggregated by gear type.

Discussion

The size distribution of *S. lewini* landed in this study of artisanal fisheries in Kenya and Mozambique suggests that the coastal fisheries in these two countries capture individuals across multiple life stages, including neonates, juveniles, and mature adults, but primarily small juveniles.

Overall, the highly skewed size structure with primarily neonates and YOY individuals being landed suggests that the artisanal fisheries in Kenya and Mozambique are heavily impacting the early life stages of this species, suggesting growth overfishing, whereby *S. lewini* are being removed from the population before they have had a chance to reproduce, and a possible concentration of fishing effort within in one or more nursery habitats.

Catch data reported to the IOTC provide potential support for the findings of the surveys presented here, confirming high overall catch volumes of sharks and rays in artisanal fisheries, and over 3,000 mt of *S. lewini* landed in the WIO between 2015 and 2024. This included 2,829 mt of the species landed in Mozambique (2023-2024 only) and 668 mt in Kenya (2018-2022). This is significant mortality for a Critically Endangered species, particularly given that the majority of landed individuals are juvenile.

Additional evidence from across the Western Indian Ocean (WIO) indicates that *S. lewini* has long been a prominent component of artisanal fisheries. Several studies from the region confirm this:

- Marshall and Barnett (1997) identified *S. lewini* as one of the most commonly caught species in Madagascar, as much as three decades ago, with its fins among the most frequently traded. Subsequent studies from Madagascar reinforce this pattern.
- In northwest Madagascar, *S. lewini* was one of the most frequently landed shark species in the artisanal bottom-set gillnet fishery going back as far as 1996 (Cripps et al. 2015).
- In Antongil Bay, northeast Madagascar, pregnant females have been documented in artisanal gill-net catches (Doukakis et al. 2011).
- In southwest Madagascar between 2007 and 2012, *S. lewini* comprised approximately 30% of the total artisanal catch, with most individuals being juveniles (Humber et al. 2017). Similar trends are observed elsewhere in the region.
- In Kenya, *S. lewini* was the most abundant species in the commercial prawn trawl fishery, again dominated by juveniles (Kiilu et al. 2019).

- *Sphyrna lewini* was also the most frequently landed shark species in artisanal fisheries at three landing sites across Kenya, over an 8-month period in 2018, almost all of which were juveniles (Osuka et al. 2025).
- In Seychelles, *S. lewini* was the second most commonly caught shark in artisanal fisheries, comprising over 18% of the total elasmobranch catch, with most individuals measuring less than 90 cm TL (SFA 2016).

Given the high catch rates of this species, its listing on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 2013 would be expected to have led to a reduction in its international trade. However, available data suggest otherwise. Since 2015, CITES trade statistics derived from the CITES Trade Database, UNEP World Conservation Monitoring Centre, Cambridge, UK, indicate multiple instances of commercial exports of *S. lewini* from WIO countries, including Kenya and Seychelles. Furthermore, confiscations of shark fins in Mozambique in 2019 and 2020 revealed that 63% belonged to *S. lewini*, highlighting the continued prevalence of this species in the illegal fin trade (Asbury et al. 2021). Globally, the species remains heavily represented in trade, as it is among the dominant species in Hong Kong fin markets (Fields et al. 2018), and accounts for a substantial proportion (85%) of CITES-listed shark and ray individuals reported in international trade as meat and fins (Pavitt et al. 2021).

The high catch and trade volumes (going back several decades) are of particular concern for a species classified as Critically Endangered, raising important concerns about its population status and likelihood of further decline. IUCN Red List assessments are often conducted at a global scale, potentially obscuring regional variability in population status. However, as early as 2006, it was estimated that *S. lewini* abundance along the South Africa east coast had declined by more than 80% over the previous three generation lengths, indicating major declines in the southwest Indian Ocean.

Connectivity studies suggest limited exchange between WIO and Indonesian populations of *S. lewini* but also indicate that males are capable of long-distance dispersal across ocean basins, while females tend to remain regionally coastal (Daly-Engel et al. 2012). This implies that populations within East Africa and the broader WIO may be interconnected.

Management implications and recommendations

If such regional connectivity exists, the implications of population declines are significant. These considerations underscore the need for coordinated, cross-border management strategies.

Accordingly, and recognizing the global declines this species has faced, *S. lewini* was recently listed on Appendix I of the Convention on the Conservation of Migratory Species of Wild Animals (CMS), which calls on Parties for “strict protection” of such species. Given that many IOTC Contracting Parties and many countries fishing in the WIO are signatories to CMS, most states impacting the stock(s) of *S. lewini* in the WIO and more broadly are obliged to provide strict protection for this species. The IOTC should similarly consider a retention ban for *S. lewini* for vessels in the IOTC vessel register.

The predominance of juveniles in catches indicates that nursery areas are being impacted, while gillnets appear to be the primary gear responsible for *S. lewini* captures. Despite listing on CMS Appendix I, bycatch in these gears would result in continued mortality. This underscores the

urgent need for the implementation of both spatial and gear-based management measures to reduce fishing pressure on the species and facilitate population recovery.

Research needs

Population genetic studies are needed to better understand connectivity within the WIO, alongside movement studies to determine habitat use and the extent of transboundary movements. Should high regional connectivity be confirmed, a regional Red List assessment would be valuable to evaluate the species' conservation status at an appropriate scale.

The limited species-level catch and trade data on this species suggests that landings data should previously have been reported at species level. Given the recent CMS Appendix I listing of *S. lewini*, many nations are obliged to strictly protect the species, eliminating landings of (and thus species-level data on landings for) the species. However, and fishery interactions or unintended bycatch, or landings in waters of nations that are not CMS Parties, should be recorded at species level, along with size and sex of each individual.

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