Original Article

DNA barcoding reveals endangered and protected elasmobranchs in Tanzanian fish markets

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Abstract

Western Indian Ocean countries have banned elasmobranch finning and enacted legislation to protect endangered elasmobranchs, however finned and morphologically deformed specimens are still landed and traded on Tanzanian fish markets. Such specimens are difficult to identify morphologically, and it is possible that protected elasmobranchs are among these. This study used DNA barcoding to uncover protected elasmobranchs in 102 specimens traded on Tanzanian fish markets. The sampled specimens revealed 23 elasmobranch species, 12 of which (52.1 %) were classified as endangered (EN) or critically endangered (CR) on the IUCN Red List. Three of the identified species (great hammerhead *Sphyrna mokarran*, oceanic whitetip shark *Carcharhinus longimanus*, and pelagic thresher *Alopias pelagicus*) are protected by Tanzanian laws. Hence, it is advised that steps be taken to strengthen law enforcement at landing sites and fish markets in the country. Furthermore, the Third Schedule of Fisheries (Amendment) Regulations of 2009 should be updated to include 11 EN and CR elasmobranchs that are not on the list. Additionally, national and regional elasmobranch conservation plans should be developed to prevent the exploitation of endangered elasmobranchs.

Keywords: DNA barcoding, cytochrome c oxidase subunit I (COI) gene, illegal trade, sharks and rays, endangered elasmobranch, East Africa

Introduction

The elasmobranch fishery has long been an important source of income and employment for coastal communities in the Western Indian Ocean (WIO) (Jiddawi and Ohman, 2002). In 2020, it accounted for 4.05 % of the total catch from Tanzanian marine waters, which is equal to 2 581.58 metric tons (URT, 2020). Total annual earnings from the fishery in 2020 were 12.9 billion TZS (approximately 5.5 million USD) (URT, 2020). The main fishing grounds for elasmobranchs in Tanzania are in areas associated with coral reefs, mangrove creeks, seagrasses, and sandbanks (Jiddawi and Ohman, 2002). The fishery has historically been exploited by traditional fishers using longline, gillnets, demersal nets, and drift gillnets (Schaeffer, 2004). In the 1990s, about 26 different species of elasmobranch were harvested in Tanzania, with the silky shark (*Carcharhinus falciformis)* dominating catch at many landing sites (Shehe and Jiddawi, 2002). Most of the harvested elasmobranchs in the country are traded in either processed or unprocessed form in local fish markets in Tanga, Dar es Salaam, Nungwi,

and Mtwara. However, because elasmobranch oil and other products are used for painting fishing boats, traditional medicine, and a variety of other purposes, the species have been severely overfished (Muhando and Rumisha, 2008). The high demand for elasmobranch fins in Asian markets has also resulted in overfishing and increased destructive fishing practices in the country (Muhando and Rumisha, 2008; Hobbs *et al*., 2019; Sachithanandam and Mohan, 2020). Hence, the shark (*Cetorhinus maximus*), whale shark (*Rhincodon typus*), silky shark (*Carcharhinus falciformis*), oceanic whitetip shark *(Carcharhinus longimanus*), porbeagle shark (*Lamna nasus*), hammerhead sharks (*Sphyrna lewini, Sphyrna mokarran, Sphyrna zygaena*), thresher sharks (*Alopias pelagicus, Alopias superciliosus, Alopias vulpinus*), short fin mako shark (*Isurus oxyrinchus),* long fin mako shark (*Isurus paucus*), *Manta* spp., *Mobula* spp., and *Rhinidae* spp. Furthermore, Tanzania

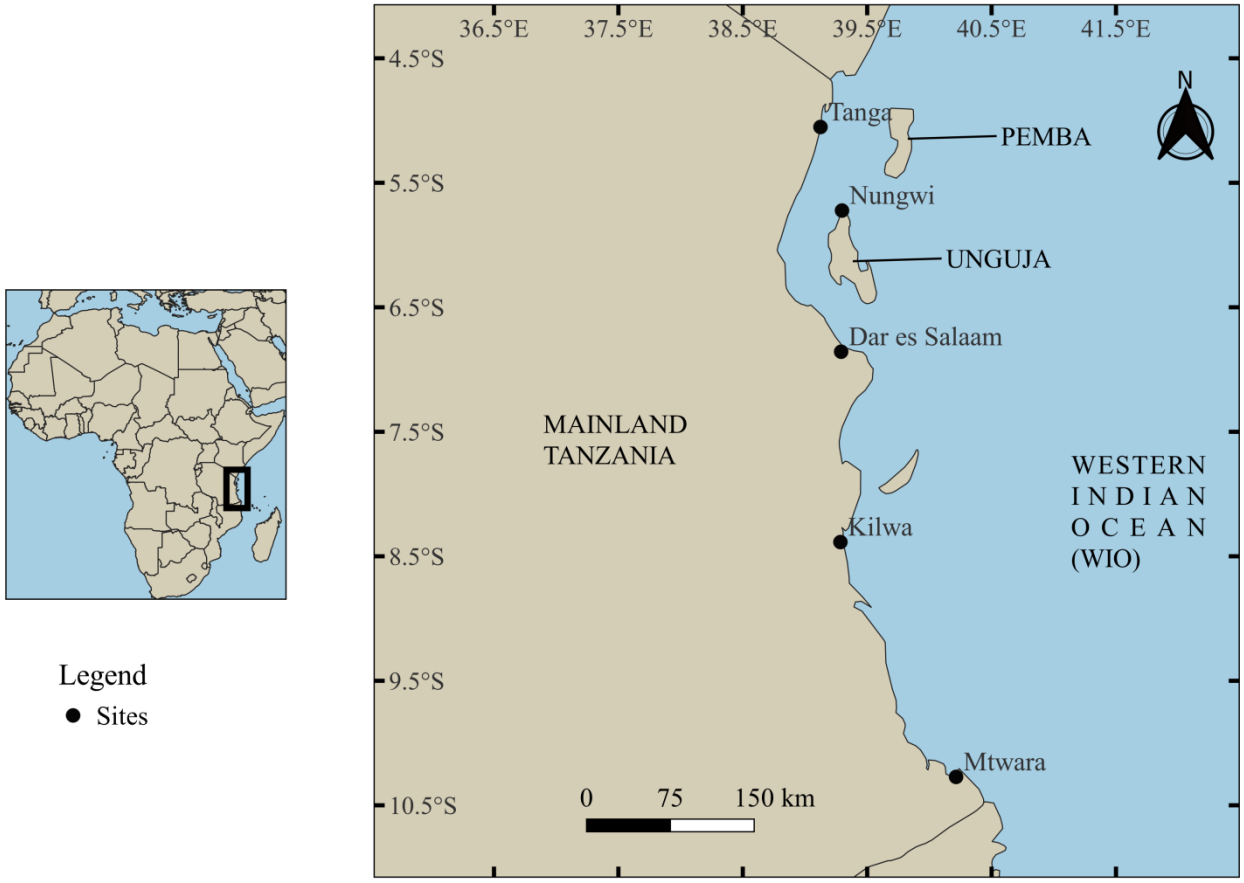

Figure 1. Map showing the sites where elasmobranch samples were collected between 2020 and 2022.

elasmobranch fishery has declined by over 80 %, and over 30 % elasmobranch species have been fished to the brink of extinction (Dulvy *et al*., 2017; Simwanza and Rumisha, 2023).

In response, international treaties such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) have acted to regulate international trade of threatened elasmobranchs (Cardeñosa *et al.,* 2018). To date, 54 species of elasmobranch are listed in CITES Appendix II, including: the great white shark (*Carcharodon carcharias*), basking banned elasmobranch finning in its waters (Regulation 6 (b) of the Deep Sea Fisheries Management and Development Regulations, 2021) and enacted measures to prohibit the purchase, offer for sale and sale of shark fins which have been removed on-board, retained on-board, trans-shipped or landed in contravention to the IOTC resolution 17/05. Additionally, the country prohibited fishing, processing, trade and export of parts, products or derivatives of any elasmobranch species listed as endangered in any International Convention to which the United Republic of Tanzania is a party (Regulation 13 (11) of the Fisheries

(Amendment) Regulations, 2009). Also, the country enacted Regulation 67 of the Fisheries (Amendment) Regulations of 2009, which prohibited fishing and trade in any part or product derived from any of the ten elasmobranch species listed in the third schedule (whale shark *Rhincodon typus*, basking shark *Cetorhinus maximus*, longheaded eagle ray *Aetobatus flagellum*, reticulate eagle ray *Aetomylaeus vespertilio*, knifetooth sawfish *Anoxypristis cuspidate*, largetooth sawfish *Pristis microdon*, wide sawfish *Pristis pectinata*, narrowsnout sawfish *Pristis zijsron*, bottlenose skate *Rostroraja alba* and great hammerhead *Sphyrna mokarran*. Furthermore, the country outlawed fishing of Oceanic white tip sharks (*Carcharhinus longimanus*) and all thresher sharks (*Alopias* spp.) in accordance with Regulation 8 (1) (a) of the Deep Sea Fisheries Management and Development Regulations, 2021. Despite the existence of such regulations, finned and morphologically deformed specimens are still landed and traded in the country's fish markets. Because such specimens are difficult to identify morphologically, it is possible that protected elasmobranchs are among those traded specimens. Thus, this study was conducted to reveal the composition and the conservation status of landed and traded elasmobranchs in Tanzanian fish markets through morphological identification and DNA barcoding. Similar approaches have been used around the world to reveal the composition of protected species of fauna in traded specimens (Haque *et al.*, 2019; da Silva Ferrette *et al*., 2019; Villate-Moreno *et al*., 2021).

Material and methods

Study area

This study was conducted along the Tanzanian coast, specifically in Tanga, Mtwara, Kilwa, Dar es Salaam, and Nungwi (Fig. 1), where the main landing sites and fish markets are located (Muhando and Rumisha, 2008). These areas have a variety of marine ecosystems, such as coral reefs, mangroves, seagrass beds, and sandbanks, which support a diverse range of elasmobranchs and other marine fauna (Richmond, 2002; Rumisha *et al*., 2015). The coastal waters in these areas are characterized by seasonal variations in

Table 1. Summary of the BLAST results obtained after comparing the obtained COI sequences of elasmobranchs from Tanzanian fish markets with those in the NCBI database.

Order	Family	Species	Sequence name	Base pair size	Accession number	Maximum score	Query cover (%)	E-value	% identity
Carcharhiniformes	Carcharhinidae	*Carcharhinus altimus*	RSS3.42	557	OQ359493	1029	100.0	0.0	100.0
		Carcharhinus falciformis	RSS3.4	567	OQ361640	1048	100.0	0.0	100.0
		Carcharhinus longimanus	RSS5.51	404	OQ361641	747	100.0	0.0	100.0
		Carcharhinus melanopterus	RSS1.19	612	OQ361642	1098	100.0	0.0	99.0
		Carcharhinus plumbeus	RSS3.11	613	OQ361643	1131	100.0	0.0	100.0
		Carcharhinus sorrah	RSS4.29	454	OQ361644	830	100.0	0.0	99.6
		Galeocerdo cuvier	RSS3.27	598	OQ361645	1127	100.0	0.0	100.0
		Loxodon macrorhinus	RSS4.28	582	OQ361648	1048	97.0	0.0	99.8
		Rhizoprionodon acutus	R11	605	OQ361660	1118	100.0	0.0	100.0
		Triaenodon obesus	RSS1.35	599	OQ361666	1107	100	0	100
	Hemigaleidae	*Hemipristis elongata*	RSS4.10	515	OQ361646	941	100.0	0.0	99.6
	Sphyrnidae	*Sphyrna lewini*	RSS4.11	566	OQ361662	1046	100.0	0.0	100.0
		Sphyrna mokarran	R4	613	OQ361663	1112	100.0	0.0	99.7
		Sphyrna zygaena	R58	623	OQ361664	1151	100.0	0.0	100.0
	Triakidae	*Mustelus asterias*	RSS5.14	576	OQ361657	1064	100.0	0.0	100.0
Lamniformes	Alopiidae	*Alopias pelagicus*	RSS3.3	635	OQ359492	1162	100	0	99.69
	Lamnidae	*Isurus oxyrinchus*	RSS3.19	584	OQ361647	1079	100.0	0.0	100.0
Myliobatiformes	Dasyatidae	*Maculabatis gerrardi*	RSS3.15	566	OQ361656	985	100.0	0.0	98.1
Orectolobiformes	Stegostomatidae	*Stegostoma tigrinum*	RSS1.39	566	OQ361665	1046	100.0	0.0	100.0
Rhinopristiformes	Rhinobatidae	*Acroteriobatus variegatus*	RSS1.29	404	OQ359491	697	100.0	0.0	97.8
		Rhina ancylostomus	RSS1.1	369	OQ361658	665	100.0	0.0	99.2
		Rhinobatos annandalei	RSS1.94	601	OQ361659	1033	100.0	0.0	97.7
		Rhynchobatus australiae	RSS5.71	609	OQ361661	1114	100.0	0.0	99.7

water circulation associated with the periods of northeast monsoon (NEM) and southeast monsoon (SEM). The NEM occurs from November to March and the SEM from April to October (Mahongo and Shaghude, 2014). Generally, there is more fishing activities during the NEM due to higher air temperature and weaker winds (Jiddawi and Ohman, 2002). The average temperatures range between 25.0 and 30.2 °C and water surface salinity between 34.5 and 35 parts per thousand (Mahongo and Shaghude, 2014).

Sampling and DNA extraction

Sampling was conducted between May 2020 and February 2022. A total of 102 elasmobranchs were sampled from landing sites, fish markets, and artisanal processors in the study area (Fig. 1). Each individual elasmobranch was first morphologically identified to species level using the available keys (Richmond, 2002; Kiszka *et al*., 2016). About 3 g of the fin tissue was dissected from each fish and stored in microcentrifuge tubes containing 99.9 % ethanol for further analysis. Genomic DNA was extracted from the sampled fin tissues by using the Quick-DNA™ Miniprep Plus Kit (Zymo Research Inc., CA, USA) according to the instructions of the manufacturer. The quality of the DNA extracts was checked on a 1 % agarose gel (Rumisha and Kochzius, 2023).

Identification of landed and traded species

Fragments of the cytochrome oxidase subunit I gene (COI) with ca. 650 base pairs were amplified from the DNA extracts of each sample in a T100™ Thermal cycler machine (Bio-Lab Inc, GA, USA) using the forward primer FishF1: 5'-TCAACCAACCACAAAGACATTGGCAC-3' and the reverse primer FishR1: 5'-TAGACTTCTGGGTGGCCAAAGAATCA-3' (Ward *et al*., 2005). Amplification reactions were done in a total volume of 25 µl consisting of 1 x OneTaq 2X Master Mix with Standard Buffer (New England BioLabs Inc., MA, USA), 0.25 µM of each primer, and 0.5 mg bovine

Table 2. Percentage composition of elasmobranch species at landing sites and fish markets in Tanzania between 2020 and 2022.

Species	Common name	Percentage composition (%)				
		Tanga	Dar	Nungwi	Kilwa	Mtwara
Carcharhiniformes		**76.0**	**83.2**	**63.2**	**75.4**	***55.5***
Carcharhinus altimus	Bignose shark			*5.3*		
Carcharhinus falciformis	Silky shark			15.8		
Carcharhinus longimanus	Oceanic whitetip shark					11.1
Carcharhinus melanopterus	Blacktip reef shark	3.5				
Carcharhinus plumbeus	Sandbar shark			*5.3*		
Carcharhinus sorrah	Spottail shark	3.5	8.3	10.5	30.0	
Galeocerdo cuvier	Tiger shark			10.5	6.0	
Loxodon macrorhinus	Sliteye shark				6.1	
Rhizoprionodon acutus	Milk shark		16.6			
Triaenodon obesus	Whitetip reef shark	65.5			3.0	
Hemipristis elongata	Snaggletooth sharks				3.0	
Sphyrna lewini	Scalloped hammerhead		16.7	10.5	27.3	11.1
Sphyrna mokarran	Great hammerhead		25.0			
Sphyrna zygaena	Smooth hammerhead	3.5	8.3	*5.3*		
Mustelus asterias	Starry smooth-hound		8.3			33.3
Lamniformes		**0.0**	**0.0**	**31.6**	**0.0**	**33.3**
Alopias pelagicus	Pelagic thresher			*5.3*		
Isurus oxyrinchus	Shortfin mako shark			26.3		33.3
Myliobatiformes		**0.0**	**0.0**	***5.3***	**0.0**	**0.0**
Maculabatis gerrardi	Whitespotted whipray			*5.3*		
Orectolobiformes		**3.5**	**0.0**	**0.0**	**0.0**	**0.0**
Stegostoma tigrinum	Zebra shark	3.5				
Rhinopristiformes		**20.7**	**16.7**	**0.0**	**24.2**	**11.1**
Acroteriobatus variegatus	Stripenose guitarfish	6.9				
Rhina ancylostomus	Bowmouth guitarfish	3.5				
Rhinobatos annandalei	Bengal guitarfish	3.5				
Rhynchobatus australiae	Bottlenose wedgefish	6.9	16.7		24.2	11.1

serum albumin. Each reaction was initially denatured at 94 °C for 3 min, followed by 35 cycles of 94 °C for 1 min, 54 °C for 1 min, and 72 °C for 1 min. The final extension of 72 °C for 10 min was added to ensure complete elongation. The quality of each PCR product was checked on a 1 % agarose gel. The successful PCR amplicons were sanger sequenced by the Macrogen Europe Lab in the ABI 3730XL automated sequencer (Applied Bio systems, Foster City, USA) using the primer FishF1. The obtained sequence for each sample was trimmed and translated into amino acid sequences using the vertebrate mitochondrial genetic code routine in the software MEGA ver. 11 (Tamura *et al.*, 2021), in order to identify and remove nuclear pseudogenes and sequencing artifacts from the dataset (Rumisha *et al.*, 2018; 2023). The taxonomic identity of each elasmobranch was revealed by comparing each edited COI sequence with the COI barcode records published in the NCBI GenBank nucleotide database using the Basic Local Alignment Search Tool (BLAST).

Results

Composition of landed and traded species

A total of 23 different shark and ray species, representing five orders and nine families, were identified from the sampled tissues, with percentage identities ranging from 97.7 to 100 % (Table 1). Similarly, the expected value for all sequences analysed was 0, while the bit score and query coverage ranged from 665 to 1162 and 97 to 100 %, respectively. Identifications derived from DNA barcoding were concordant with those resulting from morphological analysis, whenever the latter was possible.

The Carcharhiniformes were the most common, accounting for 15 (65 %) of the identified species, while

Table 3. Conservation status of elasmobranch species traded in Tanzanian fish markets between 2020 and 2022. Threat categories for IUCN: VU – Vulnerable, NT – Near Threatened, EN – Endangered, CR – Critically Endangered. CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora, CMS - Convention on the Conservation of Migratory Species of Wild Animals.

Species	Common name	Proportion in the traded samples (%)	IUCN Red List	CITES listed	CMS listed
Carcharhiniformes		72.5			
Carcharhinus altimus	Bignose shark	1	NT	Not listed	
Carcharhinus falciformis	Silky shark	2.9	VU	Appendix II	Appendix II
Carcharhinus longimanus	Oceanic whitetip shark	1	CR	Appendix II	Appendix I
Carcharhinus melanopterus	Blacktip reef shark	1	VU	Not listed	
Carcharhinus plumbeus	Sandbar shark	1	EN	Not listed	
Carcharhinus sorrah	Spottail shark	13.7	NT	Not listed	
Galeocerdo cuvier	Tiger shark	3.9	NT	Not listed	
Loxodon macrorhinus	Sliteye shark	2	NT	Not listed	
Rhizoprionodon acutus	Milk shark	2	VU	Not listed	
Triaenodon obesus	Whitetip reef shark	19.6	VU	Not listed	
Hemipristis elongata	Snaggletooth sharks	1	VU	Not listed	
Sphyrna lewini	Scalloped hammerhead	13.7	CR	Appendix II	Appendix II
Sphyrna mokarran	Great hammerhead	2.9	CR	Appendix II	Appendix II
Sphyrna zygaena	Smooth hammerhead	2.9	VU	Appendix II	Appendix II
Mustelus asterias	Starry smoothhound	3.9	NT	Not listed	
Lamniformes		8.8			
Alopias pelagicus	Pelagic thresher	1	EN	Appendix II	Appendix II
Isurus oxyrinchus	Shortfin mako shark	7.8	EN	Appendix II	Appendix II
Myliobatiformes		1			
Maculabatis gerrardi	Whitespotted whipray	1	EN	Not listed	
Orectolobiformes		1			
Stegostoma tigrinum	Zebra shark	1	EN	Not listed	
Rhinopristiformes		16.7			
Acroteriobatus variegatus	Stripenose guitarfish	2	CR	Appendix II	
Rhina ancylostomus	Bowmouth guitarfish	1	CR	Appendix II	
Rhinobatos annandalei	Bengal guitarfish	1	CR	Appendix II	
Rhynchobatus australiae	Bottlenose wedgefish	12.7	CR	Appendix II	Appendix II

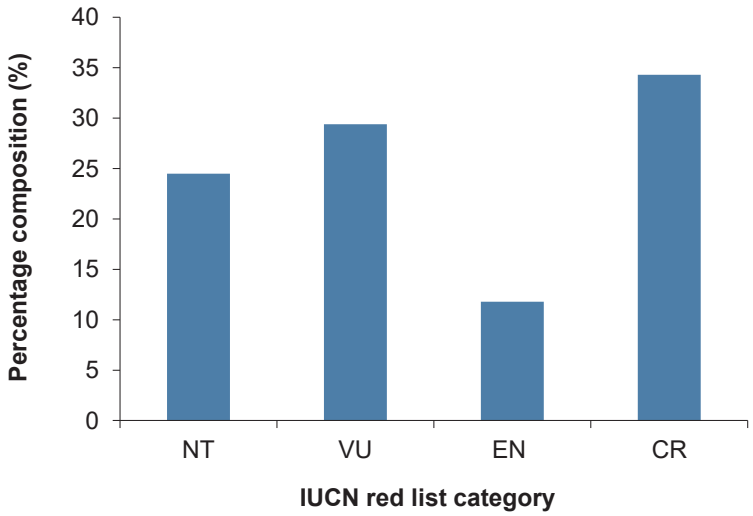

Figure 2. Percentage of threatened species in elasmobranchs traded in Tanzanian fish markets between 2020 and 2022. NT, Near Threatened; VU, Vulnerable; EN, Endangered; CR, Critically Endangered.

the Rhinopristiformes and Lamniformes were represented by four and two species, respectively (Table 1). Eight of the identified species are being reported for the study area for the first time. These include the bignose shark *Carcharhinus altimus,* the oceanic whitetip shark *Carcharhinus longimanus,* the smooth hammerhead *Sphyrna zygaena,* the starry smooth-hound *Mustelus asterias,* the pelagic thresher *Alopias pelagicus,* the whitespotted whipray *Maculabatis gerrardi,* the stripenose guitarfish *Acroteriobatus variegatus,* and the Bengal guitarfish *Rhinobatos annandalei*. Despite differences among landing sites, the spottail shark (*Carcharhinus sorrah*), the bottlenose wedge fish (*Rhynchobatus australiae*), the scalloped hammerhead (*Sphyrna lewini*) and the whitetip reef shark (*Triaenodon obesus)* were the most commonly landed and traded species in the study area (Tables 1 and 2). The whitetip reef shark (*Triaenodon obesus)* dominated the catch in Tanga, accounting for about 65.5 % of all the landed elasmobranch at the site. On the other hand, the great hammerhead shark (*Sphyrna mokarran)* dominated the catch in Dar es Salaam, accounting for 25 % of the total samples collected from the site. Conversely, the short fin mako shark (*Isurus oxyrinchus*) dominated the catch in Nungwi, while the spottail shark (*Carcharhinus sorrah)* dominated the catch in Kilwa. The catch in Mtwara was dominated by the shortfin mako shark (*Isurus oxyrinchus*) and starry smooth-hound (*Mustelus asterias)*.

Conservation status

It was observed that 78 % of the elasmobranch species identified at landing sites and fish markets in Tanzania are threatened with extinction, while about 22 % of them are near threatened (Table 3). Of those, 52.1 % are either endangered (EN) or critically endangered (CR), and accounted for approximately 46.1 % of the total catch (Fig. 2 and Table 3). Furthermore, it was revealed that about 47.8 % of the landed and traded elasmobranch species in the country are listed in CITES Appendix II, implying that they should not be exported outside the country without a CITES permit. Thresher sharks, which are protected under IOTC Resolution 12/09, great hammerhead sharks, and other elasmobranchs, which are protected under the Tanzania Fisheries Regulation 13 (11) and 67 (2) of 2009, were detected in specimens collected from fish markets.

Discussion

This study revealed 23 different elasmobranch species among the fish landed and traded in Tanzanian fish markets (Table 1). The observed number of species is lower than the number previously reported in South Africa (Fennessy, 1994) and Zanzibar (Shehe and Jiddawi, 2002) but it is higher than the number previously reported in Mozambique (O'Connor and Cullain, 2021). Because all of the aforementioned studies were conducted in the WIO, differences in the reported number of species may be attributed to the region's diverse marine ecosystems and the fact that management approaches in each country differ. However, because all of the aforementioned studies relied solely on morphological identification, which can occasionally fail to disentangle cryptic species and species with similar morphologies, the variations in

the reported number of species may also be the result of different identification techniques used. Of the 23 identified species, the Carcharhiniformes, particularly the spottail shark (*Carcharhinus sorrah*), the scalloped hammerhead (*Sphyrna lewini*) and the whitetip reef shark (*Triaenodon obesus*) were the most commonly landed and traded. High abundance of the Carcharhiniformes was also previously reported in Zanzibar (Shehe and Jiddawi, 2002; Schaeffer, 2004) and in other parts of the WIO (Fennessy, 1994). Furthermore, Rhinopristiformes, particularly the bottlenose wedgefishes (*Rhynchobatus australiae*), which are common in the WIO (Temple, 2018), were also among the most commonly landed and traded elasmobranch species in the country. The results obtained per site showed that Tanga is dominated by the whitetip reef shark (*Triaenodon obesus),* Dar es Salaam by the great hammerhead shark (*Sphyrna mokkaran)*, Nungwi by the short fin mako shark (*Isurus oxyrinchus*)*,* Kilwa by the spottail shark (*Carcharhinus sorrah)* and Mtwara by the short fin mako shark (*Isurus oxyrinchus*) and the starry smooth-hound (*Mustelus asterias*). This shows that the distribution of elasmobranch species in Tanzanian waters is not uniform and that some species may be better adapted to specific coastal habitats.

The findings of this study revealed that 18 of the 23 identified elasmobranch species (78 %) from landing sites and fish markets in Tanzania are classified as threatened by the IUCN (VU, EN or CR, Table 3). The fact that EN and CR species accounted for 46.1 % of the total elasmobranch catch shows that despite varying degrees of protection, elasmobranchs that are in danger of going extinct are still caught in large numbers and supplied to fish markets. These results are comparable to previous studies which reported that 58 % and 93 % of the traded elasmobranch products in Bangladesh and Southeast Asia are categorized as threatened by the IUCN (Sembiring *et al*., 2015; Haque *et al*., 2019). Three of the 12 EN and CR elasmobranchs caught are legally protected and specifically mentioned in Tanzanian laws: the great hammerhead (*Sphyrna mokarran*), which is protected by Tanzania Fisheries (Amendment) Regulation 67 (2) of 2009, and the oceanic whitetip shark (*Carcharhinus longimanus*) and pelagic thresher (*Alopias pelagicus*), which are both protected by Tanzania Deep Sea Fisheries Management and Development regulation 8 of 2021. The fact that the great hammerhead was previously reported in the catch (Shehe and Jiddawi, 2002) and that it accounted for approximately 2.9 % of the total elasmobranchs traded in Tanzanian fish markets between 2020 and 2022 (Table 3), shows that fisheries regulations are not strictly enforced. The presence of the oceanic whitetip shark (*Carcharhinus longimanus*) and pelagic thresher (*Alopias pelagicus*) in the catch, despite the fact that this is the first time they have been identified in the catch, provides additional evidence for a lack of law enforcement. Limited enforcement has been identified as one of the major reasons why illegal trade in protected elasmobranchs continues to thrive in many parts of the world (Haque *et al*., 2019). However, because Fisheries Officers were present at every sampled fish market and were regularly inspecting the landed and traded elasmobranchs, it is unclear why they are not enforcing the existing regulations. Therefore, if the shark fishery is to thrive, the main reasons why fisheries officers do not enforce the existing regulations should be identified and addressed.

Results of the present study also suggest that Tanzania's fisheries regulations should be revised. This is crucial because nine of the 12 EN and CR elasmobranchs are neither listed in the Third Schedule of the Tanzania Fisheries Regulations of 2009, nor are they mentioned in the Deep Sea Fisheries Management and Development Regulations of 2021, implying that they are not protected by these regulations. The fact that CR species such as the scalloped hammerhead shark (*Sphyrna lewini)* and the bottlenose wedgefish (*Rhynchobatus australiae)* were among the most traded species is alarming and calls for immediate measures to protect threatened elasmobranch in Tanzanian waters. The present study is concordant with that of Van Beuningen (2020), which showed that 50 % of traded elasmobranchs on the Tanzanian island of Pemba are threatened with extinction, implying that either existing regulations are not enforced or the regulations themselves do not adequately protect threatened elasmobranchs. Because many of the EN and CR elasmobranch species identified from specimens collected in Tanzanian fish markets are not listed in the Third Schedule of the Tanzania Fisheries regulations of 2009, it is advised that the Third Schedule be updated to include these species.

This study also revealed that among the 23 identified elasmobranch species in Tanzanian fish markets, 11 species (47.8 %) are listed in CITES appendix II. These findings are comparable to those of a previous study, which reported 14 CITES protected elasmobranch species in fish markets and landing sites in the Tanzanian island of Pemba (Van Beuningen, 2020). Because most of the fish exports come from the sampled fish

markets, there is a chance that these CITES-listed elasmobranchs are exported outside the country in contravention to CITES regulations. Therefore, there is a need to strengthen enforcement of current fisheries regulations to ensure that protected elasmobranch species do not enter fish markets and are not exported outside the country without permits.

Conclusions

Many WIO countries including Tanzania have established legislation to protect threatened elasmobranch species (Tanzania Fisheries (Amendment) Regulation, 2009; Kenya Fisheries Management and Development Act No. 35, 2016; Mozambique Marine Fisheries' Regulation (REPMAR), 2020). However, the level of protection varies across the region, with countries such as Mozambique prohibiting threatened mobulids, thresher sharks, whale sharks, basking sharks, great white sharks, and oceanic whitetip sharks, while others have prohibited only a few of the aforementioned species and other species that may not be protected in Mozambique. Because species protected by Tanzanian laws, such as great hammerhead (*Sphyrna mokarran*), oceanic whitetip shark (*Carcharhinus longimanus*), and pelagic thresher (*Alopias pelagicus*) were detected in fish markets inspected on a regular basis by fisheries officers, the main reason why fisheries officers do not enforce existing regulations should be identified and addressed. Additionally, because nine of the EN and CR species traded in Tanzanian fish markets (Table 3) are neither listed in the Third Schedule of the Tanzania Fisheries Regulations of 2009 nor mentioned in the Deep Sea Fisheries Regulations of 2021, it is advised that the regulations be urgently updated to include these species and other EN and CR elasmobranchs on the IUCN Red List. The fact that the CR scalloped hammerhead shark (*Sphyrna lewini*) and the CR bottlenose wedgefish (*Rhynchobatus australiae*) were among the most traded elasmobranchs in Tanzanian fish markets, indicates that they are in grave danger of extinction and should be protected immediately. Furthermore, because all identified elasmobranch species are either threatened or near threatened, it is recommended that steps be taken to promote sustainable fishing in Tanzanian waters and that a national plan of action for elasmobranch conservation be developed to halt exploitation of threatened elasmobranchs. Additionally, the country should implement multilateral agreements to which it is a party, particularly trade controls in CITES listed elasmobranchs and an embargo on shark finning (IOTC resolution 17/05). Lastly, a regional plan of action for elasmobranch conservation should be developed to ensure that WIO countries with similar elasmobranch stocks collaborate on a shared management strategy.

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