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Shark (Elasmobranchs) Fisheries Trend in Pakistan: Species Composition of Catch and their Conservation Status

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ABSTRACT

Sharks are important group of marine and estuarine cartilaginous fishes and hold ecological and commercial importance. Studies on the diversity, life-history and species distribution in South-East Asian countries are limited. Here, we studied the number of sharks in landings, species composition, and status of shark fishery in four fish landing sites in Pakistan including Karachi Fish Harbor, Korangi Fish Harbor, Sonmiani Fish Harbor and Gawadar Fish Harborduring 2017-2018. A total of 1.99 million sharks belonging to 11 families and 41 species were recorded from these landing sites. Significantly, higher number of sharks landed at Karachi Fish Harbor (KFH) (86.9% of the total). Ninety-six percent of the sharks fall in three families (Carcharhinidae 45%, Triakidae 35%, Hemiscylliidae 16%). Species in Lamnidae had 2% contribution whereas each of the remaining families showed <2% representation. Carcharhinidae was the most species-rich family (23 spp.), all other families were represented by 1-3 species. Two peak periods of high catches were recorded during the months of March-April and September-October, the lowest catch was recorded in the summer. Size-range data suggests that juvenile and immature individuals of all shark species are being caught as a by-catch of other targeted fishery. Twenty-six years landing data of elasmobranchs in Pakistan during the period from 1993 to 2019 revealed decreasing trend in the catch, the highest being in 1999 (54,959 metric tonnes) and the lowest during 2019 (5,793 metric tons). Majority of the shark species (85% of total) in the landing are listed as CR, EN, NT or VU, and two species categorized as LC in the IUCN Red Data List. Similarly, nine species of sharks are listed in CITES Appendix II and of these 9 species, 8 species are also listed in CMS Appendix II. On the basis of our findings, it may be concluded that sharks inhabiting the North Arabian Sea are under considerable threats of overexploitation and fisheries by-catch.

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Authors' Contribution
AJ conducted the field work, analyzed the data and writing the manuscript. SS help in statistical analysis and format the manuscript. SAA help in data collection and analysis. PJAS conceived and designed the research, provide lab facilities, checking the manuscript and finally approved the manuscript for submission.

Key words
Sharks, Conservation, CITES, Fisheries, Elasmobranchs, Shark landing

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INTRODUCTION

Sharks, a group of cartilaginous fishes consisting of 250 species, are performing well in various ecosystems for over 400 million years (Compagno *et al*., 2005; Arai and Azri, 2019). Despite their evolutionary accomplishments, many species of shark are at the brink of extinction due to unmanaged fisheries where over-fishing to meet the high demand for their fins and meat, and by-catch are most prominent reasons (Musick *et al*., 2000; Ferretti, 2010; Dulvy *et al*., 2014; McClenachan *et al*., 2016). Moreover, having complex life history traits, overexploitation of this group tends to decline their population worldwide, and hence sharks are considered as extremely vulnerable group worldwide (IUCN, 2013). Their vulnerability is further compounded by the fact that sharks are slow grower and have low productivity with long gestation time (Arai and Azri, 2019). Similarly, environmental pollution and habitat destruction exert negative impact on their wellbeing (Hutching, 2000; Polidorro *et al*., 2012).

For the purpose of conservation and protection of threatened shark species and their trade control, several international legislations have been developed (Jabado and Spaet, 2017). In 2003, four shark species were initially categorized in the Appendix II of the CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). In the last meeting of Parties in 2017, additional 12 species of shark were categorized in the Appendix II. Although these species are not threatened with extinction but their trade is prohibited to avoid the

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discordant utilization for their survival (cites.org). In addition, the convention on the migratory species (CMS) aims at conserving species that cross national boundaries or habitats beyond national jurisdiction. Migratory species of sharks at risk of extinction throughout their ranges are listed in CMS Appendix I and those with an unfavorable conservation status that would benefit the international corporation are listed Appendix II of the CMS (cms.int).

In Southeast Asian countries, scientific information regarding the shark landing is documented sporadically (Arai and Azri, 2019). A large knowledge gap still exists regarding the population of shark in the Southeast Asia, the main global consumer of shark products (Lam and Sadovy de Mitchenston, 2011). The main problem to the conservation and management of shark population in the world is the lack of information on their diversity, seasonal occurrence and fisheries in many areas (Arai and Azri, 2019).

Historically, Pakistan had no large-scale commercial shark fishery, which started gradually as artisanal small-scale activity and most of it was non-targeted by catch (Carpenter, 1997; Tesfamichael and Pauly, 2012; IOTC, 2013; Jabado and Spaet, 2017). Later on, a large-scale fishery targeting sharks has been developed involving some industrial boats (Jabado and Spaet, 2017). Fisheries reports and taxonomic checklists for sharks in Pakistan are limited (Psomadakis *et al*., 2015; Moazzam and Osmany, 2021, 2022; Osmany and Moazzam, 2022) no information is available on numbers, size ranges and sex of landed sharks. Similarly, seasonal variation in occurrence of sharks and their long-term landing trend have not been studied. Further research is inevitably required for proper management and conservation of shark fisheries in Pakistan. Here we assessed the species composition and seasonal occurrence of shark species in the commercial catch landed at various fish harbors particularly the major landing site at Karachi Fish Harbor. Long-term landing trends of sharks and rays over a period of 26 years (1994-2019) and conservation status of sharks is also presented.

MATERIALS AND METHODS

Study area and specimen

We observed the sharks at the landing sites in Pakistan during 2017-2018. The study sites included Karachi Fish Harbor (KFH; 24.8491° N, 66.9761° E) and Korangi Fish harbor (KoFH; 24.7937°N, E 67.1398°E) along Sindh coast, and Sonmiani Fish harbor (SFH; 25.4523° N, 66.5603° E) and Gwadar Fish Harbor (GFH; 25.1253°N, 62.3261°E) along Balochistan coast. The landing data, including total number of sharks species landed at each landing site per year and number of male and female sharks was acquired from Marine Fisheries Department and major traders where most of the landed sharks are processed for consumption and export. The landing sites were visited severally each month to note external morphological characteristics of at least 10 specimen of each species. Some rare species were found in less numbers. Measurements were made as per Irschick and Hammerschlag (2015) and used for identification of species according to Psomadakis *et al*. (2015) and Fishbase (https://www.fishbase.org 2023). The conservation status of all shark species was obtained from websites of IUCN Red List (https://www.iucnredlist.org) and CITES (Convention on International Trade in Endangered Species of wild flora and fauna - Appendix II; https://cites.org), and CMS (the memorandum of understanding for the Conservation of Migratory Sharks - Appendix II; https://www.cms.int).

Statistical analysis

The data were analyzed by using the PRIMER software package version 7.0 (Clarke and Gorely, 2006, 2015). Distributions of shark species at four locations were assessed using nMDS plot following Clarke and Gorely (2015). To investigate the relationships between season and number of each shark species recorded during landing, cluster analysis was conducted using the hierarchical method based on the Bray–Curtis similarity index (Bray and Curtis, 1957). Fishery landing trend was assessed using twenty-six year fisheries data (1993-2019) for shark landings retrieved from the Marine Fisheries Department. Polynomial regression by fitting highest degree (5) curves was employed.

RESULTS

Shark landings in Pakistan

A total of 1.991 million sharks landed at four fish landing sites situated in Sindh and Balochistan were recorded during 21 months study period (Table I). Forty-one species falling in 11 families were represented in the catch where species in 3 families constituting 96% of the catch (Carcharhinidae 45%, Triakidae 35%, Hemiscylliidae 16%). Species in Lamnidae had 2% contribution whereas each of the remaining families showed <2% representation (Fig. 1). Carcharhinidae was the most dominating family (23 spp.), followed by Hemiscyllidae (3 spp.), Trakaidae, Sphyrnidae, Lamnidae, Alopidae and Hemigalidae, the last five families were represented by 2 species each. Other four families had only one species each.

The landing data also depicts that significantly higher number sharks landed at KFH (86.9% of total) compared to other sites, KoFH (6.2%), GFH (5.1%), SFH (1.8%) (Fig. 2). Forty-one species of sharks were recorded from MoFH,

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Table I. Number of shark species landed at four fish landing sites located in Sindh and Baluchistan: KFH, Karachi Fish Harbor; KoFH, Korangi Fish Harbor; SFH, Sonmiani Fish Harbor at Dam and GFH, Gawadar Fish Harbor. Conservation status of all 41 species was taken from IUCN Red List. Species included in Appendix-II of CITES (*Convention on International Trade in Endangered Species of wild flora and fauna) and CMS (+ the memorandum of understanding for the Conservation of Migratory Sharks) are also indicated.

Family	Shark species	Shark landing record								Conservation Status (IUCN, CITES*, CMS+
		KFH	KoFH	SFH	GFH	Total sharks	Male	Female	Size range TL (cm)	
Alopiidae	*Alopias pelagicus*	4237	302	86	254	4879	2453	2426	134.7-142.3	EN*+
	A. superciliosus	1216	87	24	67	1394	654	740	169.1-331.3	VU*+
Carcharhinidae	*Carcharhinus altimus*	15017	1072	312	883	17284	8632	8652	87.7-184.5	NT
	C. amblyrhynchoides	12697	907	254	746	14604	7321	7283	76.3-125.7	VU
	C. amboinensis	15648	1120	321	913	18002	9231	8771	96.1-168.9	VU
	C. brevipinna	6851	490	134	412	7887	3876	4011	74-234.5	VU
	C. dussumieri	12852	917	261	765	14795	7431	7364	84.5-141.9	EN
	C. falciformis	64294	4592	1311	3765	73962	37541	36421	90.7-186.3	VU*+
	C. hemiodon	12430	889	254	734	14307	7231	7076	112-191.9	CR
	C. leucas	16585	1185	337	976	19083	9563	9520	97-122.4	VU
	C. limbatus	10866	776	221	639	12502	6231	6271	69.2-79.9	VU
	C. longimanus	738	52	15	43	848	432	416	54.9-182.3	CR*
	C. macloti	43044	3072	878	2532	49526	24764	24762	83-229.1	NT
	C. melanopterus	12584	898	254	743	14479	7145	7334	95.4-180.4	VU
	C. plumbeus	10323	737	210	607	11877	5976	5901	75.6-230.6	EN
	C. sorrah	8874	634	181	522	10211	5132	5079	36.8-74.3	NT
	Galeocerdo cuvier	2091	149	42	123	2405	1241	1164	69.8-343	NT
	Glyphis cf. gangeticus	0	1	0	0	1	1	0	61.1-112.4	CR
	Lamiopsis temminckii	0	1	0	0	1	1	0	70.1-90.8	EN
	Loxodon macrorhinus	205393	14656	4123	12312	236484	115674	120810	61.8-92.1	NT
	Negaprion acutidens	846	60	16	48	970	452	518	65-133.5	EN
	Prionace glauca	371	25	6	22	424	231	193	74-169.9	NT
	Rhizoprionodon acutus	125527	8963	2541	7383	144414	71451	72963	50.1-122.2	VU
	R. oligolinx	94215	6745	1923	5543	108426	54321	54105	33-60.1	NT
	Scoliodon laticaudus	105487	7543	2153	6251	121434	58751	62683	24.5-80.8	NT
	Triaenodon obesus	77	5	2	4	88	37	51	84.3-100	VU
Lamnidae	*Isurus oxyrinchus*	30696	2192	632	1876	35396	17643	17753	75.5-181.3	EN*+
	I. paucus	612	44	13	34	703	341	362	98.7-148.7	EN*+
Ginglymostomatidae	*Nebrius ferrugineus*	1401	101	28	82	1612	821	791	71.9-121.4	VU
Hemigaleidae	*Chaenogaleus macrostoma*	952	67	16	56	1091	531	560	44.5-90.9	VU
	Hemipristis elongata	1436	101	23	83	1643	832	811	74.3-156.9	VU
Hemiscylliidae	*Chiloscyllium arabicum*	121885	8707	2431	7132	140155	71542	68613	28.4-72.4	NT
	C. griseum	79238	5660	1613	4563	91074	45543	45531	65.7-109.8	VU
	C. indicum	67321	7834	3411	3456	82022	41280	40742	38.6-82.4	VU
Pseudocarchariidae	*Pseudocarcharias kamoharai*	26	2	1	2	31	14	17	56.6-96.5	LC
Rhincodontidae	*Rhincodon typus*	1	1	0	0	2	1	1	92-405.3	EN*+
Sphyrnidae	*Sphyrna lewini*	12589	897	254	743	14483	7143	7340	130.6-237.9	CR*+
	Sphyrna mokarran	17488	1241	356	1023	20108	11432	8676	77-265.5	CR*+
Stegostomatidae	*Stegostoma tigrinum (fasciatum)*	11	1	1	1	14	6	8	115.7-205.3	EN
Triakidae	*Iago omanensis*	275586	19681	5624	16210	317101	154356	162745	69.2-107.3	LC
	Mustelus mosis	334477	23890	6832	19675	384874	194231	190643	64.7-73.5	NT

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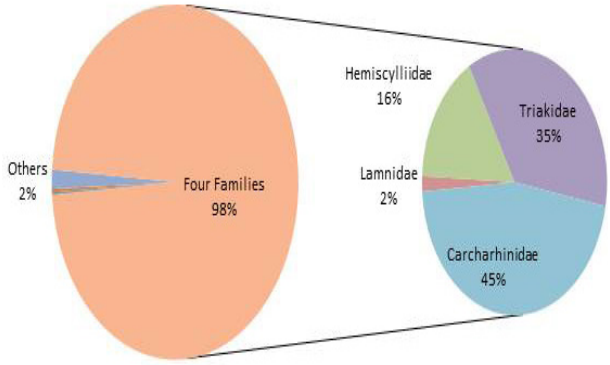

Fig. 1. Percent contribution in total catch of shark species belonging to different families recorded from four landing sites situated in Sindh and Baluchistan.

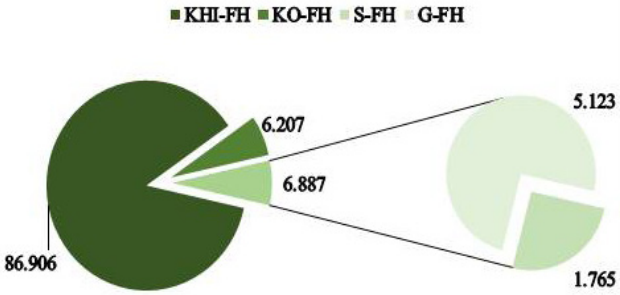

Fig. 2. Percentage of shark landed at Karachi Fish Harbor (KFH), Korangi Fish Harbor (KoFH), Sonmiani Fish Harbor (SFH) and Gawadar Fish Harbor (GFH).

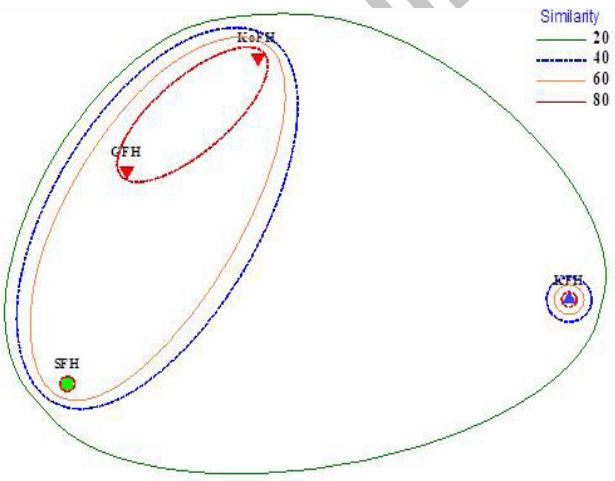

Fig. 3. Similarity between landing sites with respect to the number of sharks landed at four detrmined by nMDS analysis. Karachi Fish Harbor (KFH), Korangi Fish Harbor (KoFH), Sonmiani Fish Harbor (SFH) and Gawadar Fish Harbor (GFH).

whereas 39 spp. from KFH and 38 spp. from SFH and GFH were noted (Table II). *Rhincodon typus* only 1 specimen was recorded from each landing sites at KFH and KoFH, while one specimen each of the other two species (*Glyphis cf. gangeticus* and *Lamiopsis temminckii*) was recorded at KoFH only (Table I). A comparison was made using diversity and abundance data using non-metric MDS assessment tool which clearly demonstrated that KFH had only 20% similarity with other three sites. The other three sites had >60% similarity with each other in terms of species composition and their numbers appeared in the catches (Fig. 3).

Table II. Number of species in eleven families of sharks landed at four sites.

Family	Number of species			
	KFH	KoFH	SFH	GFH
Pseudocarchariidae	1	1	1	1
Alopiidae	2	2	2	2
Lamnidae	2	2	2	2
Hemiscylliidae	3	3	3	3
Stegostomatidae	1	1	1	1
Ginglymostomatidae	1	1	1	1
Rhincodontidae	1	1	0	0
Triakidae	2	2	2	2
Hemigaleidae	2	2	2	2
Carcharhinidae	22	24	22	22
Sphyrnidae	2	2	2	2
Total	39	41	38	38

For abbreviations see Table I.

Sharks were landed in variable numbers. Most dominant species, with >0.1M individuals recorded in landings, included seven species in three families namely, Carchirhinidae (*Loxodon macrorhinus*, NT, 0.2364 M; *Rhizoprionodon acutus*, VU, 0.1444 M; *R. oligolinx*, NT, 0.1084 M; *Scoliodon laticadus*, NT, 0.1214 M), Hemiscyllidae (*Chiloscyllium arabicum*, NT, 0.1402 M) and Triakidae (*Iago omanensis*, LC, 0.3171 M; *Mustelus mosis*, NT, 0.3845 M) (Table I). This dominant group constitutes 73% of total individuals recorded during study period. Other 13 species were frequent (20-50 thousand), 07 species were occasional (1-20 thousand) and 10 species were rarely encountered (<1000) (Table I). Although these most contributing species are not in CITES Appendix II, but they are listed as VU, NT or LC in IUCN red-list. However, some nine species of sharks appeared in landings (*Alopias pelagicus*, *A. supercilliosus*, *Isurus oxyrhinchus*,

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I. paucus, *Rhincodon typus*, *Carchrhinus falciformis*, *C. longimanus*, *Sphyrna lewini*, *S. mokkaran*) are listed in CITES Appendix II and of these 9 species, 8 species are also listed in CMS Appendix II (Table I). Considering IUCN Red List, the landing data showed that 15 species were Vulnerable (VU), 10 species were Near-Threatened (NT), 9 species were Endangered (En), 5 species were Critical constituting 85% of catch. Only 2 species were listed as Least Concern (LC) (Table I).

Seasonal variation in shark catch landed at KFH

Seasonal landing data of sharks landed at KFH show monthly variations (Fig. 4). Sharks appeared in all landings throughout the year showing two peaks of high catches during March-April and September-October. Lower catch was recorded during summer (May-August). We pooled data for four seasonal periods with respect to monsoon, i.e., Summer Inter-monsoon (SIM, February-April), Southwest monsoon (SWM, May-July), Autumn Inter-monsoon (AIM, August-October) and Northeast monsoon (NEM, November-January). The cluster analysis of pooled data considering numbers of each species caught also showed that the periods of high catches were clustered together, i.e. SIM, AIM and NEM, and the summer season (SWM) with lower catches stand separately (Fig. 5).

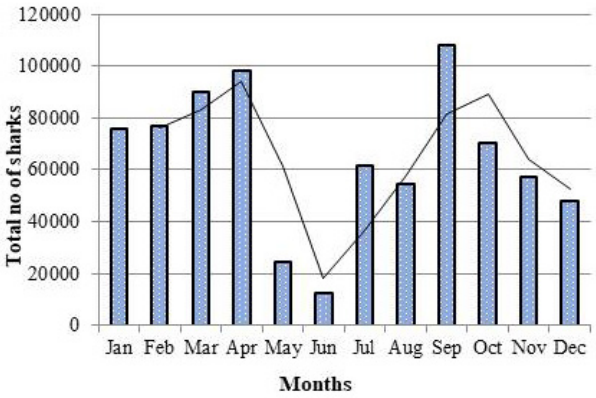

Fig. 4. Bars showing total number of sharks landed the year 2017 at Karachi Fish Harbor (KFH). The two months moving average of sharks (solid line) depicts two peak landing seasons.

Status of Elasmobranch fishery

Twenty-six years fisheries data (1993-2019) for total elasmobranch landings at KFH was retrieved from the Marine Fisheries Department. The data was assessed using polynomial regression by fitting highest degree (5) curves showing a declining trend (Fig. 6). The higher catches recorded during 1993-2010 followed a sharp decline to lower values and the continuous decreases in the catch were obvious during the next nine years up to 2019.

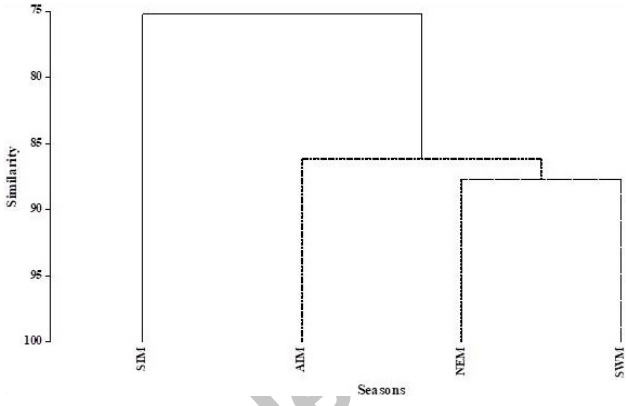

Fig. 5. Clusted analysis showing seasonal variation in number of shark species recorded during different period of year. SWM, southwest monsoon; SIM, summer inter-monsoon; ALM, autumn inter-monsoon and NEM, northeast monsoon.

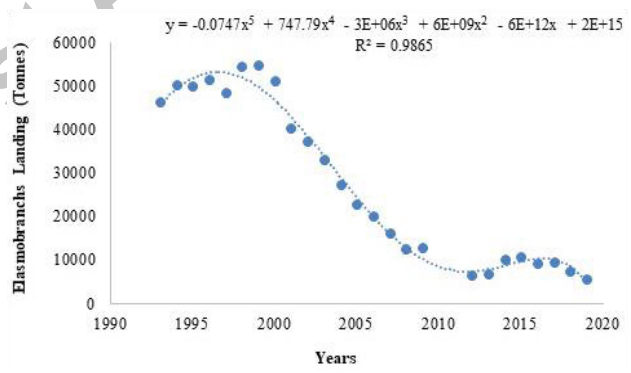

Fig. 6. Elasmobranch fisheries data depicts sharp decline over twenty-six years period (1993-2019) in Pakistan.

DISCUSSION

Like many other countries in the region, Pakistan also lacks significant data and required expertise, for example, to identify sharks properly and collect relevant data. Here we present information on shark landing, its seasonality and long-term trends in Pakistan which is in line with the Action 1 of Xiamen declaration (https://cites.org) emphasizing collection of shark fisheries data (catch, discards, effort), biological information, stock structure, nursery grounds and habitats of sharks. Xiamen declaration was adopted in the "Asian Regional Consultative Workshop on Capacity Assessments for the Implementation of new CITES Listing of Sharks and Manta Rays" (Xiamen, China, May 2014) where priority actions required for elasmobranchs

management and conservation were highlighted including, data collection, strengthening legislation, enforcement and international cooperation, strengthening conservation and management measures and enhancing training to generate human resources with capacity to deal with existing issues and challenges.

We collected data on the species composition and numbers of sharks observed in landings at various fish landing sites in Pakistan during the study period. Although little is known about the movement and habitat use patterns of sharks in in the northern Arabian Sea bordering Balochistan and Sindh coasts of Pakistan, but the 41 species recorded here in the landings are known to be distributed in pelagic, oceanic, and demersal habitats. For example, two species of thresher sharks (*Alopias pelagicus* and *A. supercilliosus*) are generally found in the epipelagic zone in both neritic and oceanic waters over continental and insular slopes and shelves (Cartamil, 2009). Similarly, all the three species of bamboo sharks occurring in Pakistan are bottom dwellers (Last *et al*., 2010). Variable movement pattern are reported for sharks in family Carcharhinidae. They typically use restricted home-range which increases with the increasing body size of different species (Conrath and Musick, 2010). *Carcharhinus sorrah* (spot tail shark) can be found on shelve of continental and insular areas (Gambang, 1994), including coral reefs and moves relatively short distances of 50 km in near-shore waters but sometimes move large distances about 1000 km (Stevens *et al*., 2000). Species in Family Sphyrnidae, found in warm tropical to temperate waters (Compagno, 1984), are highly mobile with ability to migrate extensively and are generally found throughout the assortment of ecosystems including estuaries, bays, continental shelves and offshore waters (Wells *et al*., 2018).

Coastal catches are generally landed in respective landing sites along the coast of Pakistan. It may be noted that most of the large fishing trawlers and boats from Sind and Balochistan, particularly from offshore waters, call at KFH and hence higher diversity and numbers of sharks are recorded at this site. Therefore, the shark species landed at KFH would represent their seasonal distribution in Pakistan waters. Consequently, we study the seasonal variations in composition and abundance of sharks on the basis of landing data from KFH for which monthly data was available. The two peak seasons of high catches recorded here separated by a period of low catches which may be attributed to many factors. For example, reduced fishing efforts particularly during summer, high energy SW monsoon season, when fishing remains confined to the coastal waters only (Siddiqi, 1992). Water temperature and other environmental conditions are also known to regulate distribution of animals and their reproductive cycle (Arai and Azri, 2019). Upwelled cold water of low oxygen concentration in this area can change the distribution of many animals (Banse, 1968; Siddiqi, 1992). Migration may also result in variable catches and domination of certain species at different time of the year (Henderson *et al*., 2008). The differences between life-history and habitat among the species might change the seasonal occurrence and composition of species in the particular region (Arai and Azri, 2019). A variety of bottom feature, such as, sandy and muddy substrates, cliffs, rocky outcrops, bays and other low energy habitats are discretely available along Pakistan coast to support these animals throughout their life cycle (Psomadakis *et al*., 2015) and additional habitat use may benefit foraging success and promoting growth (Knip *et al*., 2010, 2012; Arai and Azri, 2019).

Shark fishery in Pakistan is mostly untargeted. Sharks are captured as bycatch during fishing operation to target other multiple commercial species including mackerel, scads, tuna and sardines using various fishing gears, such as, line-gears, drift gill-nets, bottom trawls nets, hooks and line and long-lines (Psomadakis *et al*., 2015) and also set-bag nets and purse seine (Personal observation). Artisanal fishery has also been involved in targeting sharks presumably in low numbers (data is not available). Similarly, most sharks are also caught as bycatch in India (Gupta *et al*., 2020) and elsewhere in other parts of the world (Bonfil, 1994). Legislations and ban on certain types of nets, such as, trawl and seine nets, are widely ignored in Pakistan and other regional countries.

Comparing known length at maturity (FishBase) with size data recorded here, it is alarming to note that juveniles and immature specimen are being caught of all landed shark species. A significant numbers of pregnant female sharks have been observed during surveys (personal observation). The indiscriminate fishing practice is a serious threat for the population of sharks particularly because of the fact that they are predominantly characterized as long-lived and slow growing animals producing few off-springs (Dulvy *et al*., 2017). Furthermore, the species identified in landings are categorized according to IUCN Red List where 39 species are listed as vulnerable (24%), endangered (4%), near-threatened (54%) or critical (3%) and their total represents 84% of the total catch. In addition, another 4% of the catch are either CITES Appendix II or CMS Appendix II species.

Information regarding catch of world's shark and usage are often inadequate and regionally not even at the rudimentary level, despite the questions and arguments for the protection and sustainability of shark fisheries around the world (Rose, 1996; Baum and Myers, 2004; Lam *et al*., 2011). Like many other countries Pakistan is a data poor country. Twenty-six years data of fisheries landings

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in Pakistan clearly show a sharp decline in shark fisheries. The same has been reported for shark fisheries from different parts of the world such as Atlantic Ocean (Baum *et al*., 2003; Hutching and Baum, 2005), the Mediterranean Sea (Ferretti *et al*., 2008) and the Gulf of Mexico (Baum and Myers, 2004). Similarly, Southeast Asian countries are also known to have poor documentation of shark fisheries (Lam and Sadovy de Micheson, 2011). For example, India, a top shark harvesting country (Karnad *et al*., 2020), and Bangladesh (Bay of Bengal; Haque *et al*., 2022) are also reported have unmanaged and collapsing shark fishery. Further significant data collection, capacity building, awareness of the issue and biological data (such as, breeding behavior, feeding habitat, age at maturity, fecundity and migration) is required to understand the seasonal occurrence and movement pattern of sharks in Arabian Sea and surrounding waters and to make informed fishery management decisions in Pakistan.

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Ethical statement

The research work submitted here is Authors' original work and all parties involved in the research are being given due credit. The data obtained from other sources is properly cited and acknowledged.

Statement of conflict of interest

The authors have declared no conflict of interest.

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