Scalloped hammerhead (*Sphyrna lewini*): An important bycatch of in gillnet fisheries of Pakistan

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ABSTRACT

Presently there is no aimed fisheries for scalloped hammerhead, however, it is mainly landed as bycatch of tuna gillnet fisheries that operates in coastal and offshore waters including Exclusive Economic Zone and Areas Beyond National Jurisdiction (ABNJ). In addition, small quantities of scalloped hammerhead are caught by coastal gillnet fisheries and coastal longline fisheries. Juveniles that are known to inhabit coastal waters, bays and lagoon are mainly caught by coastal gillnet fisheries, as well as from coastal waters by tuna gillnet vessels as bycatch. An aim shark fisheries was established in Pakistan in 1988 and hammerhead sharks used to a preferred species contributing about 25 % of the total shark catches. This fisheries started to dwindle by 1999 and by 2003 it collapsed. Since then no aimed shark fisheries is being practiced in Pakistan and sharks including scalloped hammerhead are landed as bycatch of other fisheries. At present it is contributing about 7 % of total landings of pelagic sharks of Pakistan. Along Pakistan coast maximum size recorded for this species was 270 cm TL, however, most of *Sphyrna lewini* recorded were 65 and 185 cm TL. Small specimens of scalloped hammerhead sharks are caught in coastal waters and continental shelf area by coastal gillnetters whereas larger specimens (150-400 cm) are mainly caught as bycatch by tuna gillnetters. In Pakistan, *Sphyrna lewini* feeds upon bony fishes small sharks, rays, crustaceans and cephalopods whereas juveniles were observed to feed on mantis shrimp, portunid crabs, shrimp, cephalopods and small fishes. Study on fecundity in Pakistan revealed that female may have 18-34 pups (44 to 47 cm TL) mainly during April and June. Although national legislations provide protection to scalloped hammerhead, however, there is no implementation of these laws. Considering that the stocks of scalloped hammerhead are dwindling in Pakistan, therefore, there is a need for implementation on the existing legislations as well as creating awareness among the coastal communities for protection of this iconic species.

INTRODUCTION

The hammerhead sharks belonging to the family Sphyrnidae are named for the unusual and distinctive structure of their heads, which are flattened and laterally extended into a "hammer" shape called a cephalofoil. Members of the genus *Sphyrna* represented by three species are usually caught in the tuna gillnet fisheries in Pakistan as an important bycatch. These include scalloped hammerhead (*Sphyrna lewini*), great hammerhead (*S. mokarran*) and smooth hammerhead (*S. zygaena*). Winghead shark (*Eusphyra blochii*) although a demersal species but also caught by tuna gillnet vessels. Scalloped hammerhead was categorized as Critically Endangered by the IUCN Red List (Rigby *et al.*, 2022). Scalloped hammerhead used to be caught in large quantities during 1988 and 2002 by bottom set longline and gillnets which led to a major decrease in their landings in Pakistan. Present paper described their fisheries and conservation status in Pakistan.

Scalloped hammerhead (Fig1) and locally it is called "Buthar", "Katiar" (large size) or "Rocket" (large size) in Sindh and "Bhuthar", "Alwandi", "Katial" (large size), "Maish" (large size) and "Kanti" (Juveniles) in Balochistan. It was reported from Sindh Province by Compagno (1984) and Sorley (1932) and from Balochistan Province by Compagno (1984) and Zugmayer (1913). It was also reported from Pakistan without mentioning any specific location by Ahmad and Niazi (1975), Bianchi (1985), Brandhorst and Crockett (1994), Froese and Pauly (2022), Hoda (1985, 1988), Hussain (2003), Jabado and Ebert (2015), Jalil and Khalil (1972, 1981), Khan and Quadri (1986) and Psomadakis, *et al.,* (2015). Sorley (1932) and Zugmayer (1913) reported this species as *Zygaena malleus* which is a synonym of this species.

It is circumglobal species known from tropical and warm temperate seas. In the Indo-Pacific area it is known from Persian Gulf, Red Sea, East Africa and throughout the Indian Ocean; Japan to New Caledonia, Hawaii and Tahiti (Frickle *et al.,* 2022; Froese and Pauly, 2022). According to Notarbartolo-di-Sciara and Jabado (2021) it is a large circumtropical shark found from shelf to deep slope habitat including in the Arabian Sea.

HABIT AND HABITAT

It is a pelagic species which occur mainly over continental and insular shelves as well as in the deep oceanic water and occurring in the inshore waters in enclosed bays and estuaries (Fricke, *et al*., 2022; Froese and Pauly, 2022). Its occurrence in Pakistani waters is reviewed by Moazzam and Osmany (2021) whereas various aspects of its fisheries was described by Moazzam and Osmany (2022). It used to be one of the most dominating pelagic sharks in Pakistan but now it is rarely caught as bycatch of pelagic fisheries (Fig. 2). According to Borrell *et al*. (2011) *Sphyrna lewini* is also the most common hammerhead shark in the Indian seas.

This species may attain a maximum length of 430 cm TL (Froese and Pauly, 2022). Although along Pakistan coast maximum size was recorded to be 270 cm TL landed in Karachi Fish Harbour on 28 May, 2014 but most of specimens of *Sphyrna lewini* recorded from Pakistan Harbour ranged between 65 and 185 cm TL. Small specimens of scalloped hammerhead sharks are caught in coastal waters and continental shelf area by coastal gillnetters whereas larger specimens (150-400 cm) are mainly caught as bycatch by tuna gillnetters.

Fig. 1. *Sphyrna lewini*

Juveniles of this hammerhead shark are mainly occur in the inshore but move into deeper water as they grow. This was reported from almost all the areas of its distribution including India

(Borrell *et al*. 2011), Gulf of Mexico (Bonfil, 1997; Madrid *et al*., 1997), and off Hawaii (Duncan and Holland, 2006) and Mauritania (Ducrocq, 1998). In India the size range of *S. lewini* in the coastal waters to be 52–76 cm TL confirming that juveniles are more common in coastal waters (Borrell *et al*. 2011) whereas Raje *et al*. (2002) reported from Kerala, India that 98% of scalloped hammerhead caught by gillnets and landed from 1990 to 1993 were juveniles as their sizes ranged from 40 to 60 cm TL. According to Gallagher and Klimley (2018), scalloped hammerhead is highly migratory and can move long distances,. The information about migration of this species is lacking in Pakistan, although juveniles are known to be inhabiting coastal waters over the shelf.

Fisheries of Scalloped Hammerhead in Pakistan

Presently there is no target fisheries for scalloped hammerhead, however, it is mainly landed as by catch of tuna gillnet fisheries that operates in coastal and offshore waters including Exclusive Economic Zone and Areas Beyond National Jurisdiction (ABNJ). Tuna gillnets are placed 2 m below the sea surface and had an average length of 7 to 9 km. The mesh size varies between 14 and 16 cm (mode 15 cm). In additional, small quantities of scalloped hammerhead are caught by coastal gillnet fisheries (mesh size 5 to10 cm) and coastal longline fisheries. Juveniles that are known to inhabit coastal waters, bays and lagoon are mainly caught by coastal gillnet fisheries, as well as from coastal waters by tuna gillnet vessels as bycatch (Moazzam and Osmany, 2021.

Fig. 2 Landings of sharks including scalloped hammerhead at Karachi Fish Harbour (January 1998)

Fig. 3. Scalloped hammerhead shark landings at Karachi Fish Harbour in October 2019

Based on exploratory fishing that was undertaken as a part of FAO/GOB Balochistan Coast Development Project and FAO/GOP Marine Fisheries Development Project, targeted shark fisheries using multi-monofilament net and bottom set longlining was introduced in 1982 along Balochistan Province and 1986 along Sindh coast. Initially there was no major interest of fishermen in this fisheries, but because of high prices for fins and shark meat, this fisheries became popular by 1989 and about 400 fishing vessels have dedicatedly involved in shark fishing. Since multi-monofilament net was quite expensive, therefore, after 1990, major targeted shark fisheries was based on bottom set longlining.

The shark fisheries was based mainly on catching large sharks including shortfin mako shark, bull shark, pig-eye shark, spinner shark, tiger shark and hammerhead sharks (Fig.2). Hammerhead sharks used to preferred species but catch was dominated by other species but hammerhead sharks at time used to contribute about 25 % of the shark landings (Fig. 3). As sharks stocks were highly vulnerable to fishing pressure mainly because of low fecundity and slow growth, therefore, targeted shark fisheries of Pakistan started to dwindle and by 2003, this fisheries collapsed. Since then no aimed shark fisheries is being practiced in Pakistan and sharks is landed as bycatch of other fisheries (Moazzam and Osmany, 2020, 2021). Hammerhead species dominated by scalloped hammerhead are being landed at present as bycatch of tuna gillnet fisheries.

Commercial Landings

Separate statistics for hammerhead shark is not reported in the official statistics of Pakistan (Anonymous, 2012), therefore, it is not possible to determine changes in the landings of scalloped hammerhead during last few decades. On average (2008 to 2019) scalloped hammerhead contributed about 7 % in the total landings of pelagic sharks (Fig. 4).

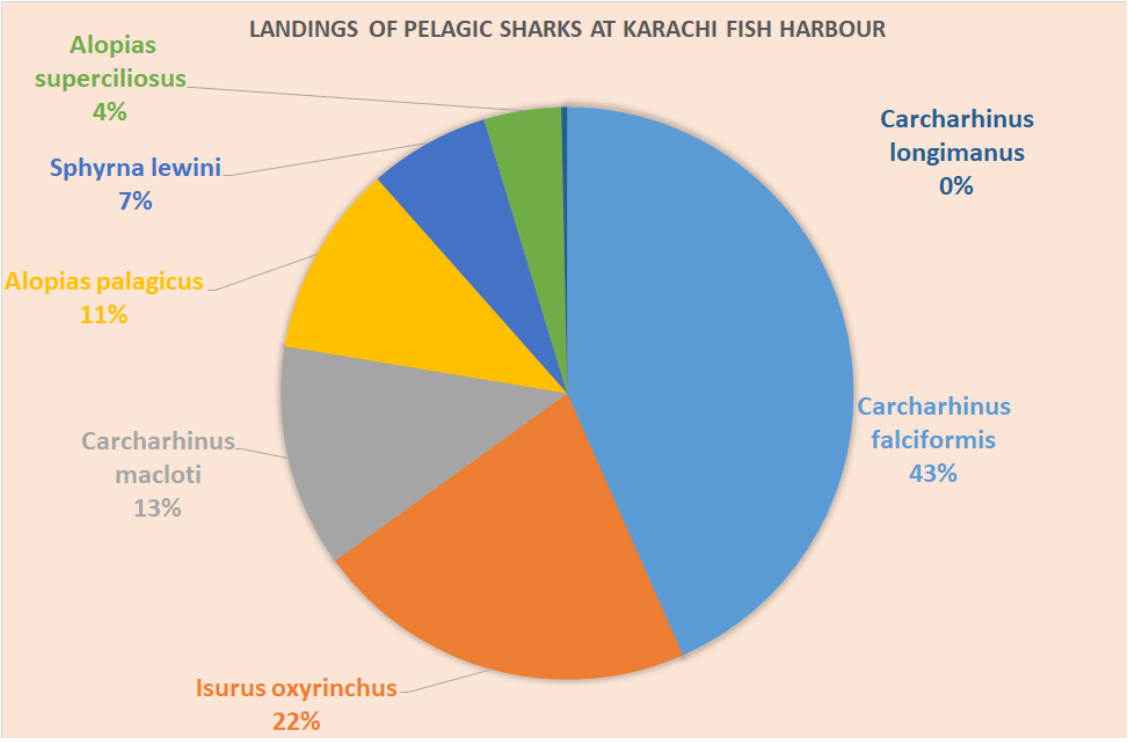

Fig. 4. Percentage contribution of pelagic sharks in commercial landings at Karachi Fish Harbour (2008-2019)

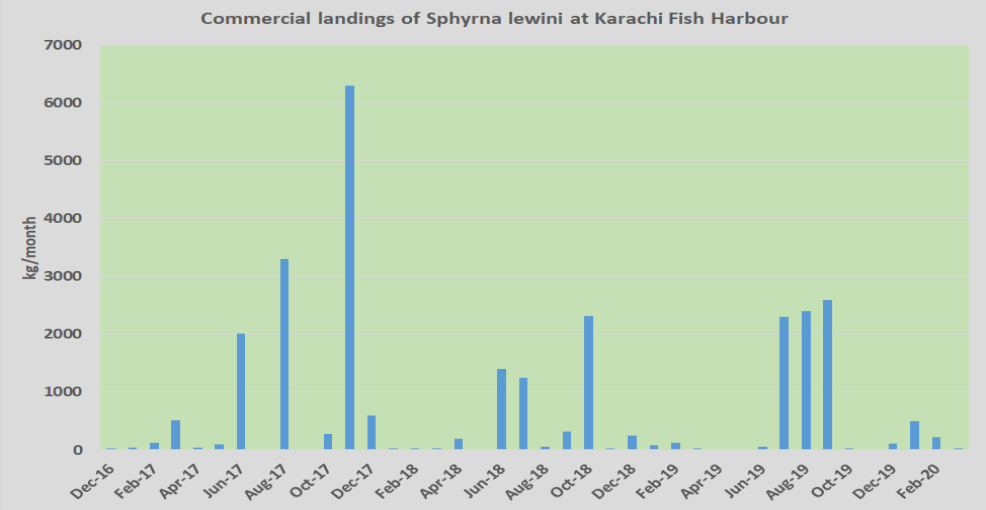

Fig.5. Commercial landings of *Sphyrna lewini* at Karachi Fish Harbour

Seasonal Distribution

A study was carried out to determine the landings of commercially important shark species at Karachi Fish Harbour during December 2016 and February 2020 (Moazzam and Osmany, 2021) which revealed that scalloped hammerhead shark is reported throughout the year with more commonly during June to December (Fig. 5). Highest landings of 6,300 kg was recorded in November, 2017. This species used to be one of the common landed sharks in 1970s and 1990s contributing up to 25 % of the total landings of pelagic shark but it landings has started decreasing since 2000. Although species specific landings data is not available but during 1990 and 2000, bottom set gillnetting (with multi-monofilament) and bottom set longlining targeting sharks were used in Pakistan for catching sharks which resulted in depletion of shark stock. Scalloped hammerhead was one of the dominating species caught during that period (Fig. 3) but now this shark is now extremely rare.

Biological Aspects

During December 2016 and February 2020, stomach contents of a few specimens of *Sphyrna lewini* were examined which revealed that this species feeds upon bony fishes including Indian mackerel (*Rastrelliger kanagurta*), shrimp scad (*Alepes djedaba*), dragonfish (*Astronesthes cyaneus*), snake mackerel (*Gempylus serpens*), rough triggerfish (*Canthidermis maculata*), Savalai ribbonfish (*Lepturacanthus savala*), shadow driftfish (*Cubiceps whiteleggii*), splitfin (*Parascombrops pellucidus*), small sharks, rays, crustaceans and cephalopods (Moazzam and Osmany, 2021). Torres-Rojas *et al*. (2006) reported that *S. lewini* feed upon 28 species of fishes and shellfishes, dominated by fishes of families Carangidae and Synodontidae, and the cephalopod (*Loliolopsis diomedeae*) off the coast of Mazatlán, Mexico.

Throughout its range of distribution, this species is considered to be a generalized and specialist feeder (Flores-Martınez *et al*. 2017; Gallagher and Klimley, 2018; Estupinan-Montano, *et al*., 2021c). Clarke (1971), Stevens and Lyle (1989) and Simpfendorfer and Milward (1993) reported that food of *S. lewini* consisted of fish, cephalopods, and crustaceans.

Since adults and juveniles occupy different habitats, therefore, the food items they consume also differs. Adults of scalloped hammerhead feed on fish, crustaceans, and cephalopods, with squid as a primary prey item (Gallagher and Klimley, 2018). Borrell *et al*. (2011) and Cabrera-

Chavez and Castillo-Geniz (2000) reported that *S. lewini* is a generalist feeder with ontogenetic dietary shifts as smaller specimens fed primarily on shrimps, the mid-size animals mainly on crabs, and the largest ones primarily on teleosts.

Stomach contents analysis of the juveniles and subadults that were caught from coastal waters in Pakistan reveals that it feed on mantis shrimp, portunid crabs, shrimp (*Solenocera* sp.), cephalopods (*Sepia* sp.) and fishes including Japanese threadfin bream (*Nemipterus japonicas*), Savalai ribbonfish (*Lepturacanthis savala*), pompano (*Trachnotus sp.*) and a large number of unidentified teleost species. Bush (2003) noticed that juvenile *S. lewini* consumed crustacean and teleost prey in Hawaii. Crustaceans were more important than teleosts by numbers (60.77%) and *Alpheus malabaricus* appears to account for about 36% of the diet. He suggested that juveniles of this species can forage opportunistically on the small prey. Rojas *et al*. (2014) observed that the cephalopod (*Loliolopsis diomedeae*) and fishes of the family Carangidae are important diet of juvenile *S. lewini* whereas red crab (*Pleuroncodes planipes*) and gerreid fishes were also major prey items in the south-eastern Gulf of California.

Juveniles scalloped hammerhead occupy coastal areas, bays and shelf areas which are mainly caught by coastal gillnettes (Fig. 6). These juveniles is known to migrate to pelagic habitat in open ocean as they grow. Estupiñán-Montaño *et al*. (2021b) observed that with such change in habitat also results in ontogenetic changes in its diet which is evident from high consumption of coastal prey up to 2 years and shifting to oceanic prey after 2-4 years and a shift to high coastal prey at more than 4 years. Their study showed migration from coastal to oceanic zones in juvenile *S. lewini*, and their return to coastal habitats as adults, potentially related to the use of coastal zones in the Eastern Tropical Pacific which is both as important feeding areas for neonates and as feeding and breeding grounds for adults. Torres-Huerta *et al*. (2008) observed presence of neonates, gravid females, and small juveniles in the east coast of the Gulf of California and in La Paz Bay which indicates that these areas are used as a nursery for *S. lewini.*

Along the coast of Pakistan, juveniles are found in coastal waters and bays whereas adults are largely caught in offshore waters. Large adults are not caught in coastal waters or mangrove areas along Pakistan coast which may suggest these areas may not be important feeding and breeding grounds for adults contrary to observation made by Torres-Huerta *et al*. (2008).

Fig. 6. Juvenile scalloped hammerhead caught from inner-shelf area along Pakistan landed at Karachi Fish Harbour

Studies carried out by Estupinan-Montano, *et al*. (2021c) suggested that *S. lewini* is a top predator occupying different trophic positions over its lifetime, consuming prey in different trophic food chain. They concluded that this species performs multiple trophic roles ranging from primary piscivores to tertiary piscivores in the trophic web of the Eastern Tropical Pacific and also consume prey at lower trophic levels such as crustaceans as well as other elasmobranchs both in coastal and oceanic regions. They have also found that scalloped hammerhead shows changes in trophic position according to sex, growth, and maturity stages and habitat use.

Jorgensen *et al*. (2009) observed that *S. lewini* diving to a depth of the sea which has extreme hypoxic zone of the oxygen minimum layer (OML) in the lower Gulf of California. Arabian Sea is also known for a pronounced hypoxia zone for most of its parts in the offshore waters (Shenoy, *et al*., 2020). Although there is no evidence of scalloped hammerhead diving to oxygen minimum zone in Pakistan or other parts of the Arabian Sea but their abundance in the area may be indicative that *S. lewini* may be foraging on the fauna inhabiting in this zone. The stomach content analysis of ta few specimens caught from offshore waters from Pakistan in January 2019 were observed to have a number of species which are found in deep waters off the shelf including Savalai ribbonfish (*Lepturacanthus savala*), shadow driftfish (*Cubiceps whiteleggii*), splitfin (*Parascombrops pellucidus*), snake mackerel (*Gempylus serpens*) and dragonfish (*Astronesthes cyaneus*) which tends to suggest that scalloped hammerhead may dive to oxygen minimum zone in the Arabian Sea for foraging.

Spaet *et al.* (2017) also provided evidence including deep diving behaviour of scalloped hammerhead shark that mesopelagic habitats in the Red Sea. They observed that in addition to nightly vertical habitat use, the shark exhibited frequent mesopelagic excursions during daytime. Similarly Hoffmayer *et al*. (2013) also noted diurnal vertical migration of scalloped hammerhead in the northern Gulf of Mexico.

The species is known to have aplacental viviparity mode of reproduction (Dulvy and Reynolds, 1997). During the present study, a number of mature female were examined which showed 18-34 pups (44 to 47 cm TL) mainly during April and June (Fig. 7). Estupiñán-Montaño *et al.* (2021a) observed that in Ecuadorian waters females contained 16–22 embryos that measured between 11.1–54.6 cm TL. Hazin, *et al*. (2001) have observed that the gravid females had between 2 and 21 embryos or pups, with 3 to 38 cm TL from north western Brazil. Torres-Huerta *et al*. (2008) observed a fecundity of 32 embryos in the Gulf of California whereas the birth size was found to be between 41 and 53 cm TL. Fecundity of this species ranges from 13–23 pups in Eastern Pacific to 12–38 pups in Western Pacific and 30–40 pups in Northwest Gulf of Mexico (Cortés, 2000). The number of embryos in pregnant females ranged from 14 to 41, with a mean of 25 in Indonesian waters (White *et al*., 2008). These studies indicates that fecundity in *S. lewini* varies with area and size of female.

Compagno, *et al.* (2005) reported that adults of scalloped hammerhead sharks are highly migratory and have an unusual coastal-pelagic life history. They may be schooling over seamounts and near continental and insular shelves. Information about such migration is not reported from Pakistan whereas no nursery area for *S. lewini* is known from the area, however, juvenile scalloped hammerhead are occasional caught by gillnet and trawlers that operated in inner shelf along Pakistan coast but there is a need to undertake study to identify nursery area for this species.

Fig. 7. Developing embryos dissected out of a female *Sphyrna lewini* landed at Karachi Fish Harbour

Marketing

Scalloped hammerhead shark fetches good prices in local market mainly because of its fins which are exported in dry form to Hong Kong. Despites restrictions on international trade, as this species is included in CITES Appendix-II, but still fins are exported to Hong Kong under disguise of dried fish. Fins of scalloped hammerhead sharks are preferred and prized by consumers in the Hong Kong fin trade markets as compared to other shark species (Abercrombie *et al*. 2005). Its meat is locally consumed along with meat of other shark species.

Specific Conservation Measures

Commercial fishing is considered to be the greatest threat to scalloped hammerhead shark population, and such exploitation occurs on every major continent (Baum *et al*. 2007; Gallagher and Klimley, 2018). It is estimated that 1.3–2.7 million scalloped hammerhead (and smooth) sharks appear in the shark fin trade globally each year (Clarke *et al*. 2006a, 2006b). Scalloped hammerhead sharks are highly vulnerable to pelagic longline and bottom longline bycatch (Gallagher and Klimley, 2018). This species is also vulnerable to bycatch of other fishing gears such as trawls, driftnets, purse-seines, and also artisanal fisheries because juveniles may be caught in the inshore fisheries (Baum, *et al.*, 2007). Although no species related landings data for shark species is available in Pakistan but major decrease in catches of scalloped hammerhead shark was noticed after 1999.

Considering its dwindling stocks globally this species is included in Appendices-II of CITES (restriction on trade) and CMS (migratory species conserved through agreements. It is considered as a highly migratory species, Annex I of the 1982 Convention on the Law of the Sea.

Scalloped hammerhead is considered to be one of most endangered shark in the area of its distribution because of uncontrolled fishing especially juveniles are being caught as bycatch in most global fisheries. Although size frequency data has not been collected and analysed during the present study, however, juveniles are still abundantly caught by gillnet fisheries, as

bycatch, in both coastal and offshore waters of Pakistan. It is noticed that quantity of scalloped hammerhead shark caught by gillnet vessels has substantially decreased in last 15 years.

In Pakistan, there was no legislation was placed for the protection of sharks including scalloped hammerhead. On the persuasion of WWF-Pakistan, both maritime provincial fisheries department have made legislations protecting species listed under CITES putting a ban on catching, landing and marketing of important species including scalloped hammerhead shark. In addition, Although scalloped hammerhead is listed on Appendix-II of the CITES, therefore, it is illegal to export these fins without valid permission from the national CITES management authority (Ministry of Maritime Affairs in case of Pakistan) but still fins of pelagic sharks find its way into Hong Kong shark fin market in the disguise of dried fish.

Sindh Wildlife Department has enacted the Sindh Wildlife Protection, Preservation, Conservation and Management Bill, 2020 which includes sharks in First Schedule which included "Protected Species". However, Sindh Wildlife Department does not have infrastructure and manpower to control fishing, therefore, no action under this law has been taken.

National CITES law (Pakistan Trade Control of Wild Fauna and Flora Act, 2012), provincial fisheries legislations 2016 and Sindh Wildlife Protection, Preservation, Conservation and Management Bill, 2020 provides legal protection to scalloped hammerhead, however, implementation of these legislations is still lacking, therefore, fishing and trade of scalloped hammerhead including export of its fins are being continued unabated.

Scalloped hammerhead sharks are commonly taken by a range of fisheries in the Indian Ocean. They are extremely vulnerable to gillnet fisheries. Because of their life history characteristics such as relatively long lived (over 30 years) and have relativity few offspring (<31 pups each year), the scalloped hammerhead shark is considered vulnerable to overfishing. There is no quantitative stock assessment or fishery indicators currently available for scalloped hammerhead shark in the Indian Ocean therefore the stock status is unknown. Despite the absence of stock assessment information, there is a need to take a cautious approach by implementing management actions for scalloped hammerhead sharks. While mechanisms exist for encouraging Indian Ocean countries to comply with their recording and reporting requirements of IOTC Resolution 18/07 but no species specific management measures are implemented by IOTC.

Pelagic sharks including scalloped hammerhead are important component of the marine ecosystems of offshore waters over continental shelf, slope and deep oceanic waters. These sharks are usually top predators in the pelagic food chain and play important role as oceanic production dynamics. In Pakistan, these are caught by a large fleet of gillnetters that operate in coastal waters (over continental shelf), in the EEZ, in the ABNJ and sometimes fishing in the waters of other countries like Yemen and Somalia (Moazzam, 2011, 2012a-d). Fecundity in most pelagic sharks including scalloped hammerhead is low (up to 41 pups). As most of the species of pelagic sharks including scalloped hammerhead are highly migratory in nature, management at global, regional and national levels are necessarily required for conservation of pelagic sharks. There is a need to identify pupping areas for scalloped hammerhead as well as areas which are nursery ground which are located in coastal areas so as to ensure protection of juveniles. The need for creation of awareness among fishermen communities for protection

of sharks cannot be overemphasized as control of overfishing can be effectively implemented if fishermen are engaged in such efforts.

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