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SPECIES COMPOSITION, COMMERCIAL LANDINGS, DISTRIBUTION AND SOME ASPECTS OF BIOLOGY OF SHARK (CLASS PISCES) OF PAKISTAN: LARGE DEMERSAL SHARKS

Hamid Badar Osmany[1] and Muhammad Moazzam[2*]

[1]*Department, Government of Pakistan, Fish Harbour, West Wharf, Karachi 74000, Pakistan*
[2]*WWF-Pakistan, D-305, Block 6, PECHS, Karachi 75400, Pakistan 1[2]Marine Fisheries*
*Corresponding author: mmoazzamkhan@gmail.com

ABSTRACT

Sharks are considered important component of the commercial landings in Pakistan which are harvested using different fishing gears including handline, longline and gillnets along coastal and offshore waters. Demersal species of sharks are main contributor of the elasmobranch landings. Large demersal sharks are represented by 6 species belonging to 4 genera. Bull shark (*Carcharhinus leucas*), seems to be most dominating among the large demersal sharks followed by pigeye shark (*Carcharhinus ambionensis*), tiger shark (*Galeocerda cuvier*), sicklefin lemon shark (*Negaprion acutidens*) and zebra shark (*Stegostoma fasciatum*). Spinner shark (*Carcharhinus brevipinna*) is seldom reported in commercial catches. These large demersal sharks were reported to be of common occurrence during 1970's to 1990's in Pakistan, however, their landings started dwindling since 2000.

Over-exploitation because of large fishing fleet in Pakistan is believed to be a major factor affecting population of sharks in general and large demersal sharks in particular. Of the 6 species, *Stegostoma fasciatum* is considered endangered (EN) according to IUCN Red List whereas two species *Carcharhinus leucas* and *Galeocerda cuvier* are near threatened (NT) and *Carcharhinus brevipinna* and *Negaprion acutidens are* vulnerable (VU). *Carcharhinus ambionensis* is considered data deficient (DD). None of the large demersal sharks are included in the Appendix-II of CITES, therefore, there is no restrictions on their international trade. These species are also not protected under national fisheries legislations, therefore, continued exploitation of large demersal sharks in Pakistan as well as in most other regional countries may lead to major reduction in their commercial catches, depletion of their stock or even their extinction.

Keywords: Large demersal sharks, *Carcharhinus ambionensis, C. brevipinna, C. leucas, Galeocerda cuvier, Negaprion acutidens, Stegostoma fasciatum,* over-exploitation.

INTRODUCTION

Sharks are commercially harvested in Pakistan mainly as bycatch of trawling, gillnetting and longlining. At present, there is no aimed fisheries for sharks in Pakistan (Moazzam and Osmany, 2021), however, pelagic sharks are mainly caught through gillnets fisheries being used for catching tuna in the offshore areas of Pakistan (Moazzam and Osmany, 2022). Bulk of the remaining sharks landed at Karachi Fish Harbour and other landing centres along the coast of Pakistan are caught as bycatch of trawling, coastal gillnetting, longlining and hand-lining.

Large demersal sharks were target of aimed fishery using bottom-set gillnets (multi-monofilament) and bottom-set longlines during 1986 and 2000. In addition, there used to be a reasonably large handline fisheries based mainly in coastal village of Balochistan prior to 2000. However, because of depletion of the stocks of shark, these fisheries died down by 2000. Even prior to 1999, there used to be an important shark fisheries based in Balochistan, as substantial part of fleet was engaged in catching of shark (Siddiqui, 1956). It may be pointed out that from Balakot (Lasbela, Balochistan), an archaeological site of Indus Civilization (Harappan Era-3000-1700 BC), teeth of bull shark were discovered (Belcher, 2003, 2018) which tends to suggest the utilization of large demersal sharks by the coastal communities, possibly for food.

Under the national legislations, there is a blanket ban on the catching of all sharks as these are included in the Appendix-I (Protected Animal) of Sindh Wildlife Protection, Prevention, Conservation and Management Act, 2020. However, Sindh Wildlife Department do not have any mechanism to ensure implementation on this ban. None of the large demersal sharks reported from Pakistan are protected under any national fisheries legislations. Under Sindh Fisheries Ordinance, 1980 and Rule No. 5(3) SO (FISH) / L & A) dated 18 May 2016 a ban is imposed on catching, marketing and sale of some shark species found in Sindh whereas under Balochistan Sea fisheries Ordinance 1970 and Rule No. SO (Coord.) Fish/2-I/2013/3148-54 dated 8 September, 2016 there is a ban on catching, retention, marketing and trade of some sharks found in Balochistan, however, these two laws do not include any demersal species except sawfishes.

International and local trade of large demersal sharks is not controlled as these are neither national legislation for their protection nor these are included in any appendices of CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). According to global conservation status (IUCN Red list), some species of large demersal sharks are considered as critically endangered, endangered, vulnerable, near threatened or data deficient (Moazzam and Osmany, 2021) however, no species of large demersal sharks assessed for CMS (Convention on the Conservation of Migratory Species of Wild Animals). Tiger shark (*Galeocerda cuvier*) is the only species of large demersal sharks which is considered as highly migratory species and included in the Annex I of the 1982 Convention on the Law of the Sea (FAO, 1994).

Sharks, like other teleosts and elasmobranchs are mainly landed at Karachi Fish Harbour, the main fish landing Centre along Pakistan coast. It is estimated that more than 80 % of the commercial shark landings is routed through Karachi Fish Harbour. Information about sharks (Selachii) is known through the work of Moazzam and Osmany (2021; 2022), however, no detailed information is available on demersal shark fisheries. Demersal shark species are categorized on the basis of marketing and disposal into three types; large demersal species (species generally larger than 2 m TL), medium demersal species (between 1.0 and 2 m TL) and small demersal sharks (less than 1.0 m TL). Present paper deals with large demersal sharks being landed at Karachi Fish Harbour and including some aspects of biology of important large demersal shark species including pig eye shark (*Carcharhinus ambionensis*), spinner shark (*C. brevipinna*), bull sharks (*C. leucas*), tiger shark (*Galeocerda cuvier*), sicklefin lemon shark (*Negaprion acutidens*) and zebra shark (*Stegostoma fasciatum*).

MATERIALS AND METHODS

In order to obtain information about seasonal changes in the landings and some biological aspects of large demersal shark, observations were recorded at Karachi Fish Harbour which is the main landings of large demersal sharks in Pakistan on daily basis from December 2016 to March 2020. During this period estimated catch of all large demersal sharks was recorded. In the collection of this data staff of Fishermen's Cooperative Society based in Karachi Fish Harbour has also provided support which is greatly acknowledged. The paper also encompasses biological aspects of large demersal sharks including their food and reproduction (mainly fecundity). The paper also narrates details about management and conservation of each species of large demersal shark.

RESULTS AND DISCUSSION

Large demersal sharks are Elasmobranchs which primarily inhabit bottom areas of coastal as well as offshore waters of Pakistan mainly restricting on the continental shelf area. Sometimes large demersal shark species are also found in pelagic environment, however, these species are largely bottom dwellers.

Six species of large demersal sharks belonging to Order Charcharhiniformes (Family Carcharhinidae)-5 species and Order Orectolobiformes (Family Stegostomatidae)-1 species are reported from Pakistan. These are alphabetically dealt in the present paper.

Carcharhinus amboinensis (Müller & Henle 1839)
(Fig.1-2)

Fig. 1 *Carcharhinus amboinensis*

Habit and Habitat: The pigeye shark is a large coastal shark (Fig. 1), which is called "more mangra," or "kandri" in Sindh and "warrok" in Balochistan. Its juveniles are called "more" or 'kandri" in Sindh and "gwark" in Balochistan. It is widely distributed circumglobally in tropical and warm temperate seas except eastern Pacific (Fricke and Eschmeyer, 2022). It is known from Eastern Atlantic (Nigeria), Mediterranean and Indo-West Pacific are including Persian Gulf, Gulf of Aden, South Africa, Madagascar, Pakistan, Sri Lanka, Indonesia, Papua New Guinea and Australia (Froese and Pauly, 2022). It presence and distribution in Pakistan is described by Moazzam and Osmany (2021).

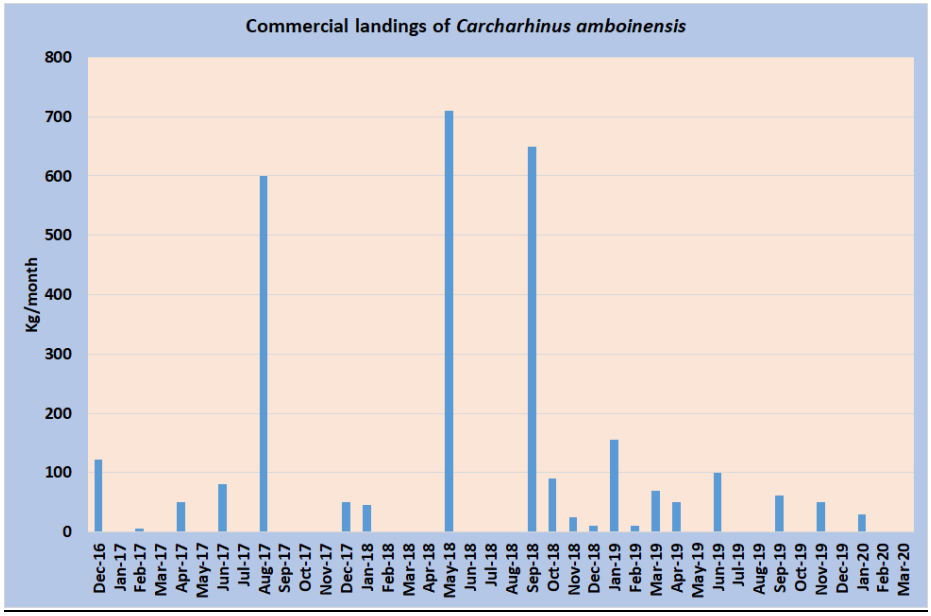

Fig. 2. Commercial landings of *Carcharhinus amboinensis* at Karachi Fish Harbour.

Seasonal Distribution: There is no distinct seasonal pattern of landings of pigeye shark in Karachi Fish Harbour (Fig. 2). It is almost landed in 20 months out of 39 months study period. Highest monthly landings of 710 kg was recorded in May 2018 whereas in September, 2018 monthly landings was reported to be 650 kg and in May, 2018 it was reported to be 600 kg. Landings in the other months during the study period were less than 155 kg. It may be pointed out that there is no aimed fisheries for sharks in Pakistan since last 2 decades, therefore, landings are based on bycatch of fishing operations such as trawling, gillnetting and longlining in the coastal area over the shelf. Being large, these are seldom caught in the other fishing gears except in longlines. Juveniles are caught mainly as bycatch of fishing operations in coastal areas especially in bays and near the mouth of the creeks in Sindh and lagoons in Balochistan. There is little data available on seasonality and distribution of pigeye shark due to difficulty in the identification. It is difficult to identify bull shark because it is difficult to distinguish it from *Carcharhinus leucas*. Pigeye shark has smaller second dorsal fin (first-to-second height ratio ≤3.1:1 in *C. leucas* versus >3.1:1 in *C. ambionensis*) and the notch in its anal fin margin forms an acute angle (versus a right angle in *C. leucas*). This species also usually has less tooth rows in the lower jaw (10–12 on each side versus 12–13 in *C. leucas*).

Biological Aspects : Pigeye shark is considered to be large achieving a maximum length of 280 cm TL (Randall *et al.*, 1990). A specimen measuring 266 cm TL was landed in Karachi Fish Harbour on 17 May, 2013 whereas large specimens exceeding 220 cm TL are frequently landed at Karachi Fish Harbour and other landing centres. Pigeye shark is an inhabitant of inshore waters over the continental and insular shelves (Compagno, 1984). It may also be found in shallow bays and estuaries, as well as off the open coast but not ascending rivers (Compagno and Niem, 1998). Although it is a demersal species but can also be found throughout the water column (Last and Stevens, 1994).

Knip *et al*. (2011a) in their study at Cleveland Bay, north Queensland (Australia) during 2008 and 2010 tracked 43 juvenile pigeye sharks and observed that these juvenile are associated strongly with shallow turbid habitats. They further observed that home ranges consistently remained in areas adjacent to creek and river mouths. Knip, *et*

al. (2011b) reported that juvenile pigeye sharks respond to seasonal freshwater inflow by moving away from areas of strong flow in tropical near shore waters.

Pigeye shark feeds mainly on teleosts (croakers, flatfishes, cutlass fishes), chondrichthyes (requiem sharks, catsharks, angel sharks, guitarfishes, stingrays, and eagle rays), cephalopods (squid, cuttlefish and octopus), crustaceans (shrimps and lobsters), molluscs (gastropods), sea snakes, dolphin and carrion (Cliff and Dudley, 1991; Compagno *et al*., 1989; Compango and Niem, 1998; Kinney, *et al*., 2011). Cliff and Dudley (1991) observed that this shark prefers to hunt close to the sea bottom, however, it can take prey from anywhere in the water column. Sharks and rays were observed to be more prominent in the stomach content in pigeye sharks from South African than those from other regions. According to Cortés (1999), the food of pigeye shark consists of decapod crustacean (7.40 %), molluscs (2.0 %), marine mammals (2.0 %), teleosts (56.3 %), Chondrichthyes (28.0 %), squid and cuttlefish (5.6 %).

Reproduction mode in pigeye sharks is viviparous and placental (Dulvy and Reynolds, 1997), with 3 to 13 in a litter at two-year intervals. The gestation period is about 9 to 12 months depending on location. According to Cortés (2000) fecundity was observed to be minimum 6, maximum 13 in the eastern Indian Ocean, minimum 3 and maximum 7 in south-western Indian Ocean and according to Compagno (1984) minimum 3, maximum 13 in the Mozambique Channel off Madagascar. No pregnant female was dissected during the present study, therefore, its fecundity in Pakistan is not known. The size at birth was reported to be about 43 to 53 cm TL (Compagno and Niem, 1998). According to White, *et al*., (2006), the born pups have a size of 60-70 cm TL in Madagascar.

According to Tillett *et al.* (2011), female *C. ambionensis* matures at 13 years and lives more than 30 years whereas male matures at 12 years and survives more than 26 years. They calculated theoretical asymptotic length ($L\infty$) for female to be 267. 2 ($\pm$11.94) cm with a growth coefficient (k) of 0.145 $year^{-1}$ whereas theoretical asymptotic length for males was 254.0 ± 13.056 cm and $k = 0.161$ $year^{-1}$.

Marketing: There is specific market for pigeye sharks in Pakistan. Its meat, like meat of other sharks, is consumed locally whereas its fins are exported to Hong Kong. There is no legislation in place for controlling catching, landing and marketing of this shark, therefore, there is no restriction on export of its fins. Its offal is dried and used as a raw material for fish meal.

Being considered as aphrodisiac, juveniles and foetuses of pigeye shark are one of the highest priced seafood commodity in Pakistan. Pregnant females, therefore, have much high prices in the landing centres as compared to males and non-pregnant females. Juveniles are mainly caught at the areas adjacent to the mouth of creek system of the Indus Delta and in Sonmiani Bay around and near the entrance of Miani Hor lagoon. Juveniles are also caught at the mouth of Kalmat Khor, bays along Balochistan coast especially in Gwater Bay near the mouth of Dasht River.

Specific Conservation Measures: No information about stocks of pigeye shark in Pakistan is available, however, noticeable reduction in the catches of this species is reported during last 40 years. There is no management regime in place for conservation and protection of the stocks of this species in Pakistan and in the regional countries. Pigeye shark is assessed globally as Data Deficient (DD) under IUCN Red List. It is not evaluated by CMS and CITES. Pigeye shark is believed to be sensitive to fishing pressure due to its patchy distribution, low abundance, late age at maturity and limited fecundity (maximum 13), therefore, there is a need for the development of a management plan for pigeye sharks restricting or putting a ban on catching, landing and marketing in Pakistan especially in view of high demand for its juveniles which puts extra pressure on the recruitment process.

Carcharhinus brevipinna (Müller & Henle 1839)
(Fig.3-5)

Habit and Habitat: The spinner shark is a slender and has grey-bronze colour (Fig. 3). It is called spinner because of its distinctive aerial "spinning" behaviour at the surface. In Pakistan (both Sindh and Balochistan) it is called "shid" or "shidda". The spinner shark lives in subtropical, tropical, and temperate regions, ranging from inshore to offshore waters over continental and insular shelves (Froese and Pauly, 2022). The spinner shark is widely distributed in Atlantic, Mediterranean and Indo-West Pacific areas (Frickle and Eschmeyer, 2022). In the western Atlantic it is known from Cape Cod, Massachusetts (U.S.A.) to the southern waters of Brazil. In the eastern Atlantic Ocean, it is found from Spain to Namibia, including the southern Mediterranean Sea. In the Indo-West Pacific, the spinner shark is found in the Red Sea, south to South Africa, eastward to Indonesia, northward to Japan, and then south to Australian waters (Burgess, 2009; Froese and Pauly, 2022). Bull shark is found up to a depth of 100 m and its juvenile is found in coastal waters and generally may move into shallower bays with tides. It presence and distribution in Pakistan is described by Moazzam and Osmany (2021).

Fig. 3 *Carcharhinus brevipinna*

Seasonal Distribution: There is no distinct seasonal pattern of landings of spinner shark in Karachi Fish Harbour (Fig. 4). It is almost landed in 23 months out of 39 months study period. Highest monthly landings of 800 kg was recorded in November 2017 whereas in May, 2018 monthly landings was reported to be 400 kg and in June, 2017 it was reported to be 330 kg. Landings in other months during the study period were less than 270 kg. It may be pointed out that there is no aimed fisheries for sharks in Pakistan since last 2 decades, therefore, landings are based on bycatch of fishing operation such as trawling, gillnetting and longlining in the coastal area over the shelf. There is little data available on seasonality and distribution of spinner shark due to an inability to distinguish it from other members of the genus *Carcharhinus.* They are frequently mistaken for blacktip sharks (*Carcharhinus limbatus*) as they have a superficially similar appearance. However, spinner sharks grow to a larger size than blacktips and its anal fin has distinctly black tip whereas *C. limbatus* do not have such blacktip.

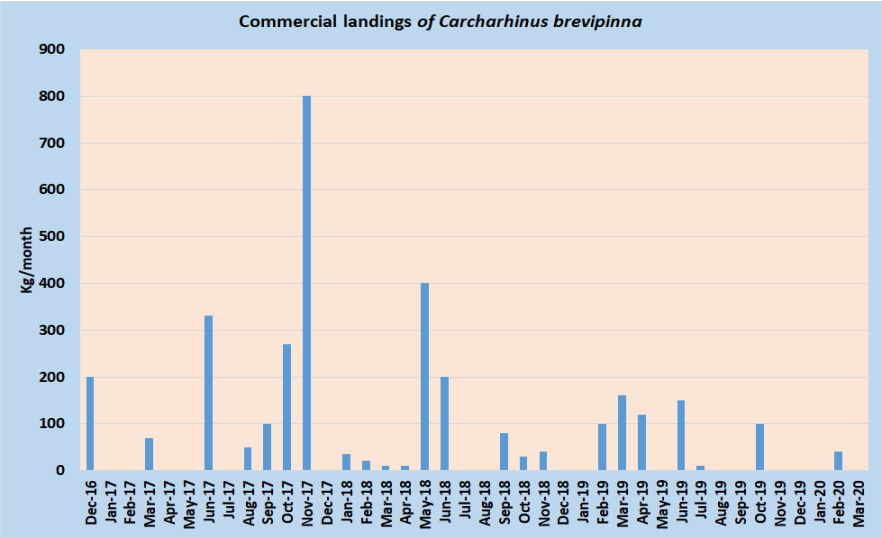

Fig. 4. Commercial landings of *Carcharhinus brevipinna* at Karachi Fish Harbour.

Biological Aspects: Spinner shark is considered to be large with a maximum length of 300 cm TL (Froese and Pauly, 2022). A specimen measuring 239 cm TL was landed in Karachi Fish Harbour on 11 April, 1999 whereas large specimens exceeding 170 cm TL are frequently landed at Karachi Fish Harbour and other landing centres. The spinner shark grows relatively fast compared to other species and upon reaching maturity, grows approximately 5 cm/year. Spinner shark is known to attain a maximum age of 11 years, however, largest known specimens may be of 15-20 years age (Burgess, 2009).

Spinner sharks feed primarily on small teleost including members of family Carangidae (jacks/trevallies), Clupeidae (sardines/herrings), Elopidae (tenpounders), Engraulidae (anchovies), Gerridae (mojarras), Haemulidae (grunts), Mugilidae (mullets), Pomatomidae (bluefish), Sciaenidae (croakers), Scombridae (bonitos), and

Cynoglosssidae (tounge-soles), unidentified fishes. Squid, cuttlefish and octopi (Compagno (1984). According to Compagno *et al*., (1989) it also feed on squid/cuttlefish and small sharks. According to Cortés (1999) the food of spinner shark consists of decapod crustacean (2.00 %), benthic algae (1.00 %), teleosts (90.60 %), chondrichthyes (0.50 %), squid and cuttlefish (5.90 %).

The spinner shark is known to be an active, fast swimming shark which may leap out of the water in pursuit of praise. They often swim through schools of small fish, spinning and snapping at fish and may breach the surface of water and spinning in the air to a height of 6 m above the water surface. This sharks is known to follow fishing vessels to feed on the discarded bycatch (Compagno, 1984).

Reproduction in spinner sharks is viviparous and placental (Dulvy and Reynolds, 1997). It has the smallest ova known for any viviparous shark (Capape, *et al*., 2003). Fecundity of this shark is 3 to 20 (usually seven to 11) and gestation period of 11–15 months (Burgess 2009). The reproductive cycle is biennial (Castro 1993). The juveniles are found in shallow estuarine waters which is believed to be a strategy for protection against predators. Sivadas *et al*. (2013) reported landing of a spinner shark at Tharuvaikulam, Tuticorin, India in August, 2012 which has 18 pups, nine pups in each uterus. In one uterus, there were 5 males and 4 females pups, whereas the other uterus contained 3 males and 6 females. Pups were 31 to 53 cm TL. The length at birth was reported to 66–77 cm in the north-western Atlantic (Fowler, *et al*., (2005), 61–69 cm off Tunisia (Capape *et al*., 2003) and 60 cm off South Africa (Van der Elst and Borchert, 1993). During the present study, 6 pups were dissected out from a female each having a size 45-48 cm (Fig. 5a). A juvenile was capture in Indus Delta (Fig. 5b) which indicates that the shallow estuarine waters are used by this species as nursery area.

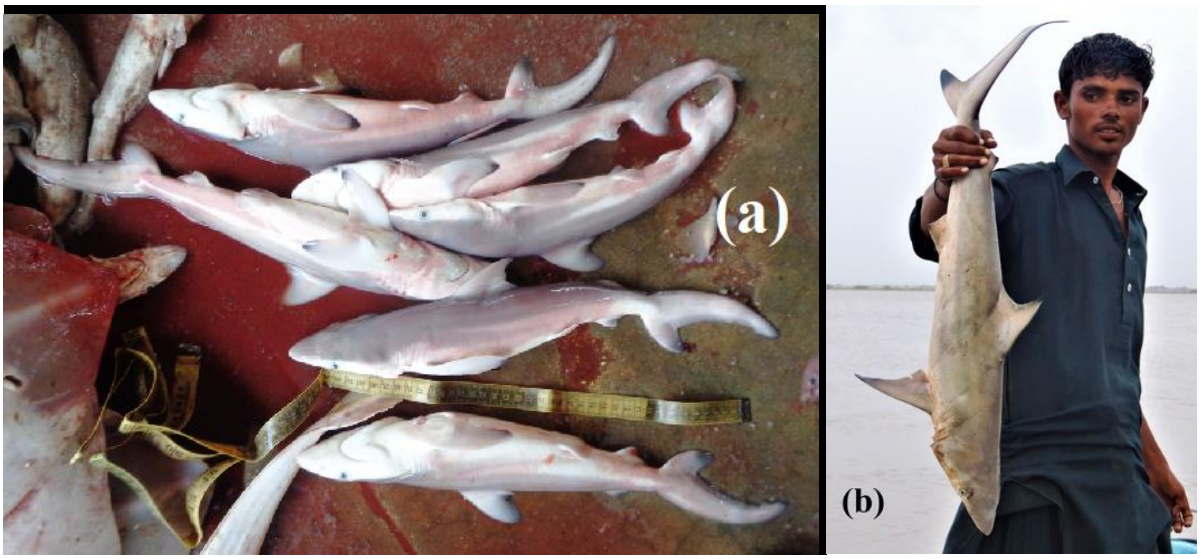

Fig. 5. Foetuses dissected from a female spinner shark (*Carcharhinus brevipinna*) at (a) Karachi Fish Harbour; (b) caught in Indus Delta at Kharro Chan.

Joung e*t al.* (2005) calculated theoretical asymptotic length for spinner shark (L_∞) to be 288.2 cm TL, growth coefficient (k) = 0.151, age at 0 length (t_0) = -1.988 year^{-1} for females; and L_∞= 257.4 cm TL, k = 0.203, t_0 = -1.709 year^{-1} for males.

Marketing: There is specific market for spinner sharks in Pakistan. Its meat, like meat of other sharks, is consumed locally whereas its fins are exported to Hong Kong. There is no restriction on catching, landing and marketing of this shark, therefore, there is no restriction on export of its fins. Its offal is dried and used as a raw material for fish meal. Unlike, pigeye and bull sharks there is no specific market for juveniles or foetus of *C. brevipinna*.

Specific Conservation Measures: No information about stocks of spinner shark in Pakistan is available, however, noticeable reduction in the catches of this species is reported during last 40 years. There is no management regime in place for conservation and protection of the stocks of this species in Pakistan and in the regional countries. Spinner shark is assessed as globally as Vulnerable (VU) in IUCN Red List. It is not evaluated by CMS and CITES.

Like other large sharks, *Carcharhinus brevipinna* is sensitive to fishing pressure because of late age at maturity and limited fecundity (3-20 pups). Its use of inshore waters for its nursery areas, make them susceptible to habitat

destruction due to development of coastal areas (Compagno, *et al*. 2005). There is a need for development of a management plan for spinner sharks restricting or putting a ban on its catching, landing and marketing in Pakistan.

Carcharhinus leucas (Müller & Henle 1839)
(Fig. 6-11)

Fig. 6. *Carcharhinus leucas*

Habit and Habitat: This species is commonly known as bull shark (Fig. 6-7). In Sindh, it is called "more mangra" or "kandri" and in Balochistan it is called "warrok". Its juveniles are called "more" in Sindh and "gwark" in Balochistan. It is a coastal shark species that inhabits shallow waters especially in bays, estuaries and lagoons (Compagno, 1984). Bull shark is known to have a cosmopolitan distribution in tropical and subtropical waters. It is known from Western Atlantic: (Massachusetts, USA to Argentina), Eastern Atlantic (Morocco, Senegal to Angola), Indo-Pacific (Kenya and South Africa to India and Viet Nam to Australia), Southern Baja California (Mexico to Ecuador and Peru), Africa (in freshwater found in rivers of West Africa from Gambia River to Ogowe River) and in the Cuanza in Angola (Froese and Pauly, 2022). It presence and distribution in Pakistan is described by Moazzam and Osmany (2021).

It ascends rivers and at places, inhabits lakes and other water bodies (Compagno and Niem, 1998; Hasan, *et al*., 2021). According to Allen *et al*. (2002) it can swim fast and capable of covering great distances (up to 180 km in 24 hours). They have been reported 3,700 km up the Amazon River in Peru, and over 3000 km up the Mississippi River, in Illinois (Froese and Paul, 2022). Hasan *et al*. (2021) reported occurrence of bull shark from Sungai Mawai Lama, about 25 km inland, Kota Tinggi District, Johor (Peninsular Malaysia). In Pakistan, it is known from major part of the Indus estuary especially in Khobbar Creek which still receive water directly from the River Indus. It is sometimes caught at Sajan Wari and Jhangi Sar in lower reaches of the Indus River. Barreiros and Gadig (2011) and Gausmann (2021) also mentioned occurrence of *C. leucas* in the Indus River and its estuary. Young bull sharks may enter rivers and can be found hundreds of km from the sea (Eccles, 1992; Heemstra and Heemstra, 2004; Heupel *et al*., 2010). Heupel, M. and Simpfendorfer (2011) observed that the presence of bull shark juveniles in estuarine habitats may be an strategy for better survival because of limited predation and competition in such habitats.

Bull shark is also known to migrate within the oceanic waters (Daly *et al.*, 2014; Werry, *et al*., 2011). According to Simpfendorfer and Burgess (2009) this species may migrates in the western Atlantic north along the coast of the U.S. during summer, swimming as far north as Massachusetts, and then return to tropical climates in winter. No such migration is known from Northern Arabian Sea (along Pakistan coast), however, it is regularly caught throughout the year from coastal and offshore areas.

Seasonal Distribution: Bull shark is the most common large demersal sharks being landed in the Karachi Fish Harbour and other landing centres along Pakistan coast. Although no distinct seasonal pattern of landings of bull shark was observed but it was observed to be landed in 29 months out of 39 months study period (Fig.8). Highest monthly landings of 5,860 kg was recorded in October 2018 whereas in August, 2018 monthly landings was reported to be 2,370 kg and in July, 2018 it was reported to be 1,160 kg. This species was landed throughout the year in 2019 except in May and November. Peak in 2019 was observed in July and August whereas lowest landings was observed in February 2019 when only 40 kg o-f bull sharks was landed in Karachi Fish Harbour. It is pointed out that here is no aimed fisheries for sharks in Pakistan since last 2 decades, therefore, landings are based on bycatch of fishing operations such as trawling, gillnetting and longlining in the coastal area over the shelf. Being large, these are seldom caught in the fishing gears except in longlines. Juveniles are caught mainly as bycatch of

gillnet fishing operations in coastal areas especially in bays and near the mouth of the creeks in Sindh and lagoons in Balochistan.

Fig. 7. Large specimens of Carcharhinus *leucas* landings at Pishukan, Balochistan

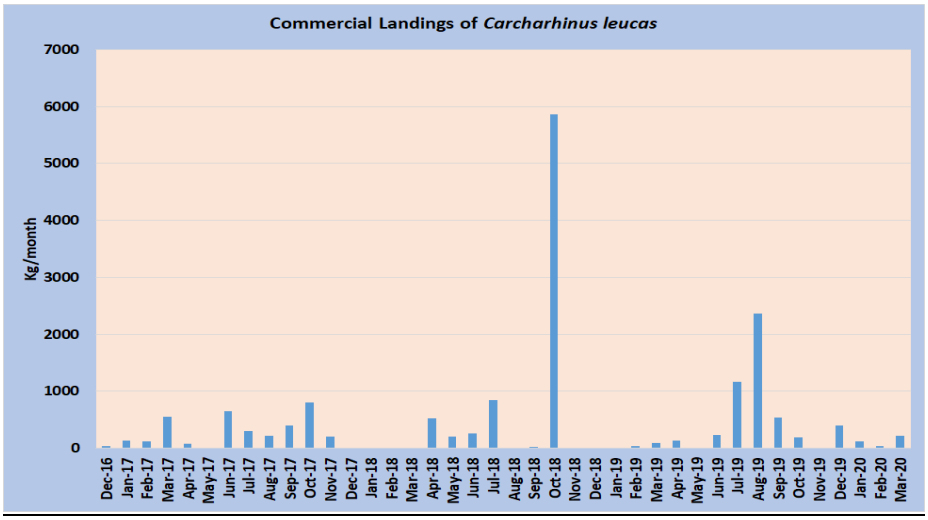

Fig. 8. Commercial landings of *Carcharhinus leucas* at Karachi Fish Harbour.

Biological Aspects: This is considered to be one of the largest shark being landed at Karachi Fish Harbour and other landing centres along Pakistan coast (Fig. 7). It is reported to achieve a maximum length of 400 cm (Compagno, *et al*., 2005). A specimen measuring 365 cm TL was landed in Karachi Fish Harbour on 22 August, 2019 whereas large specimens exceeding 250 cm TL are frequently landed at Karachi Fish Harbour and other landing centres. Bull shark prefers to inhabit shallow coastal waters but may be occur up to a depth of 150 m.

During the study, stomach contents of a number of specimens were examined which reveals that this species feeds mainly on teleosts, chondrichthys and rarely- cephalopods (squids or cuttlefish). Obtuse barracuda (*Sphyraena obtusata*), cobia (*Rachycentrum canadum*), giant catfish (*Netuma thalassinua*), Arabian gurnard (*Pterygotrigla arabica*) and orbicular batfish (*Platax orbicularis*) were observed to be present in three bull shark dissected in October, 2019. The stomach also contain a small unidentified shark and two semi-digested Indian sqiuid (*Uroteuthis*

duvaucelii). Stomach of two juveniles dissected at Keti Bundar (a landing centre within Indus Delta), contained Bloch's gizzard shad (*Nematalosa nasus*), white sardine (*Escualosa thoracata*), Dussumier's thryssa (*Thryssa dussumieri*) and debris (dominated by decayed mangrove leaves.

According to Compagno *et al*. (2005), bull sharks in the western Atlantic feed on teleosts (mullet, tarpon, catfishes, menhaden, gar, snook, jacks, mackerel, snappers, and other schooling fish), chondrichthyes (stingrays and juvenile sharks)and sea turtles, dolphins, crabs, shrimp, sea birds, squid, and even dogs. Cortés (1999) reported that the diet of bull shark consists of decapod crustaceans (2.6 %), molluscs (0.20 %), benthic algae (4.00 %), mammals (3.10 %), sea turtles (1.40 %), sea birds (0.50), teleosts (52.30 %), chondrichthyes (35.40) and squid/cuttlefish (0.50).

According to Snelson *et al.* (1984), bull shark feeds upon teleosts such as catfishes (*Arius felis, Bagre marinus*), clupeidae (*Brevoortia sp.*), Sciaenidae (*Cynoscion sp.*), , tenponder (*Elops saurus*), sea bream (*Lagodon rhomboids*), mullets (*Mugil sp*.), snake eel (*Ophichthus sp*.), toadfish (*Opsanus tau*), Spanish mackerel, lizardfish (*Synodus foetens*), hogchoker (*Trinectes maculatus*) and unidentified snapper, chonrichthyes (juvenile bull shark; sting ray *Dasyatis sabina*; unidentified sting ray) and shrimp, whereas Compagno et al (1989) reported swimming crab of Family Portunidae (*Callinectes sp*.), unidentified squids, turtles, mantis shrimp, unidentified shrimp and gastropod, unidentified flatheads, grunter, kob, mullet, rockcod, sardine, sea bream, snapper and soles.

Bull sharks are viviparpous like other sharks. A female dissected at Karachi Fish Harbour was observed to have 9 pups having a length of 45 to 49 cm TL (Fig. 9). According to Allen *et al*. (2002) and Smith (1997), the litter size was observed to up to 13. Litter sizes in bull shark ranged from 5 to 14 embryos (Pirog *et al.*, 2019). The mother gives birth after a 10-11 month gestation period (Simpfendorfer and Burgess 2009). Size at birth was reported to be 56-81 cm TL. Hoarau *et al*. (2021) reported the size at birth is larger in the Reunion Island than elsewhere in the world, varying from 92.30 to 100.00 cm. The size at maturity was reported to be 157-226 cm TL for males and 180-230 cm TL for females (Simpfendorfer and Burgess 2009), however, according to Pirog *et al.* (2019) males and females reached maturity at about 234 cm and 257 cm total length respectively.

Age of maturity in bull shark is reported to be between 15-25 years (Compagno *et al*. 2005) whereas Branstetter and Stiles (1987) reported age of maturation for female to be 18 years (180-230 cm TL) and for males14-15 years (157-226 cm TL). Growth rates have been calculated by Thorson and Lacy (1982) in Lake Nicaragua to be about 16-18 cm per year at early ages whereas Branstetter and Stiles (1987) estimated the growth rate to be 4-5 cm per year at later stage.

Fig.9. Foetuses dissected from a female bull shark (*Charcharhinus leucas*) in Karachi Fish Harbour.

Branstetter *et al.* (1987) found the smallest mature females to be 325 cm TL and 318 cm TL, and the smallest mature males were 310 cm TL and 312 cm TL in the Gulf of Mexico and the north-west Atlantic, respectively. In Florida, Clark and von Schmidt (1965) reported that the smallest mature female was 297 cm TL but also found a larger 332 cm TL female to be immature. Holmes, *et al.* (2015) reported mature females to have a size of 326 cm TL and for males 297 cm TL. According to Emmons *et al*. (2021), asymptotic length (L_∞) in bull shark to be 372 cm FL; growth coefficient (k) to be 0.067 and length-at- birth (L_0) to be 65.8 cm FL. Growth of tiger sharks from western Australia was slower than that of tiger sharks from most other regions, but similar to that observed on the eastern coast of Australia (Emmons *et al*., 2021).

Marketing: There is specific market for bull sharks in Pakistan. Its meat, like meat of other sharks, is consumed locally whereas its fins are exported to Hong Kong. There is no restriction on catching, landing and marketing of this shark, therefore, there is no restriction on export of its fins. Its offal is dried and used as a raw material for fish meal.

Like pigeye sharks, juveniles and foetuses of bull shark are considered to have aphrodisiac properties, thus, fetches high prices in the local markets in Pakistan. Pregnant females, therefore, have much high prices in the landing centres as compared to males and non-pregnant females. Juveniles are mainly caught at the mouth of creek system of the Indus Delta and bays along Balochistan coast (Fig. 10-11).

Fig. 10. Juvenile of bull shark collected from the offshore Indus Delta

Fig. 11. Juvenile of bull shark collected from the Keti Bunder, a part of Indus Delta.

Specific Conservation Measures: No information about stocks of bull shark in Pakistan is available, however, noticeable reduction in the catches of this species is reported during last 40 years. López-Garro and Zandía (2021) pointed out that *Carcharhinus leucas* is particularly vulnerable to anthropogenic actions because of its permanence in coastal ecosystems. The bull shark is not legally protected in any part of its range of distribution as well as there is no management regime in place for conservation and protection of the stocks of this species in Pakistan and in the regional countries. According to IUCN Red List, bull shark is assessed as globally as Near Threatened (NT). It is not evaluated by CMS or CITES. Karl *et al*., (2011) suggested that the conservation and management of bull sharks may require a coordinated combination of local, regional and global efforts in view of its philopatric habits and the relatively low levels of mtDNA genetic diversity. International cooperation will be as important to the proper management and conservation of the bull shark as it is for other long-lived, broadly distributed and geographically subdivided, marine vertebrates (Bowen and Karl, 2007; Dankel *et al.* 2008).

Considering major decrease in the landing of bull shark there is a need for development of a management plan for bull sharks restricting or putting a ban on catching, landing and marketing in Pakistan ss. There is a need to have a ban on catching its juveniles in the Indus Delta and lower reaches of the River Indus.

Galeocerda cuvier (Péron and Lesueur 1822)
(Fig. 12-15)

Fig. 12. *Galeocerda cuvier*.

Habit and Habitat: This species is commonly known as tiger shark (Fig. 12) and in Sindh, it is called "aiyan more" and in Balochistan it is called "nar-mani". It is usually found up to depths of 140 m on continental and insular shelves as well as entering river and estuaries and lagoons (Compagno, 1984; Simpfendorfer 2009). It is bottom-dweller but may also occur in pelagic environment (Mundy, 2005). Tiger sharks is known to undergo seasonal migrations as they move into temperate waters from the tropics in warmer months and return to the tropics during the winter. They also make long distance oceanic migrations and are capable of traveling long distances in a short time (Simpfendorfer 2009).

It is a circumglobal in tropical and temperate waters in Western Atlantic (Massachusetts, USA to Uruguay, including Gulf of Mexico and the Caribbean), Eastern Atlantic (Iceland to Angola), Indo-Pacific area (Persian Gulf, Red Sea and East Africa to Hawaii and Tahiti, north to southern Japan, south to New Zealand) and Eastern Pacific (southern California, USA to Peru), including the Revillagigedo, Cocos, and Galapagos islands (Froese and Pauly, 2022). It presence and distribution in Pakistan is described by Moazzam and Osmany (2021).

Seasonal Distribution: Tiger shark is the one of the large demersal sharks that is landed in small numbers in the Karachi Fish Harbour frequently. Although no distinct seasonal pattern of landings of tiger shark was observed but it was observed to be in landed in 17 months out of 39 months study period (Fig. 13). Highest monthly landings of 80 kg were recorded in March, 2019 whereas in October, 2017 monthly landings was reported to be 70 kg and in February 2019 it was reported to be 50 kg. It may be added that tiger shark is not found in bulk quantities but also reported to be either singly or a few specimens (maximum 3). Being large, these are seldom caught in the fishing gears such as trawl net but occasionally are hooked in longlines. It is pointed out that here is no aimed fisheries for sharks in Pakistan since last 2 decades, therefore, landings are based on bycatch of fisheries such as trawling, gillnetting and longlining in the coastal area over the shelf.

Biological Aspects: It is reported to achieve a maximum length of 750 cm (Vidthayanon, 2005). According to Schneider (1990), the common length of tiger shark is 500 cm. Assadi and Dehghani (1997) reported that tiger sharks with a maximum size of 750 cm TL are known to occur in the Persian Gulf and Oman Sea. A specimen measuring 339 cm TL was caught in the offshore waters of Pakistan on 11 October, 2019 (Fig. 14) whereas large specimens exceeding 300 cm TL are frequently landed at Karachi Fish Harbour and other landing centres.

During the present study, stomach content of three large tiger sharks were examined which revealed that it feeds mainly on teleosts (unidentified) and elasmobranchs (one head of an unidentified guitarfish was observed) and semi-digested whose taxonomic enumeration could not be done. According to Compagno *et al*. (2005) tiger shark has a

reputation to eat almost anything. The food of tiger shark may include sea turtles, rays, other sharks, bony fishes, sea birds, dolphins, other marine mammals squid, cuttlefish, various crustaceans, terrestrial animals (like cats, dogs, and goats) and carrion (Compagno *et al*., 2005).

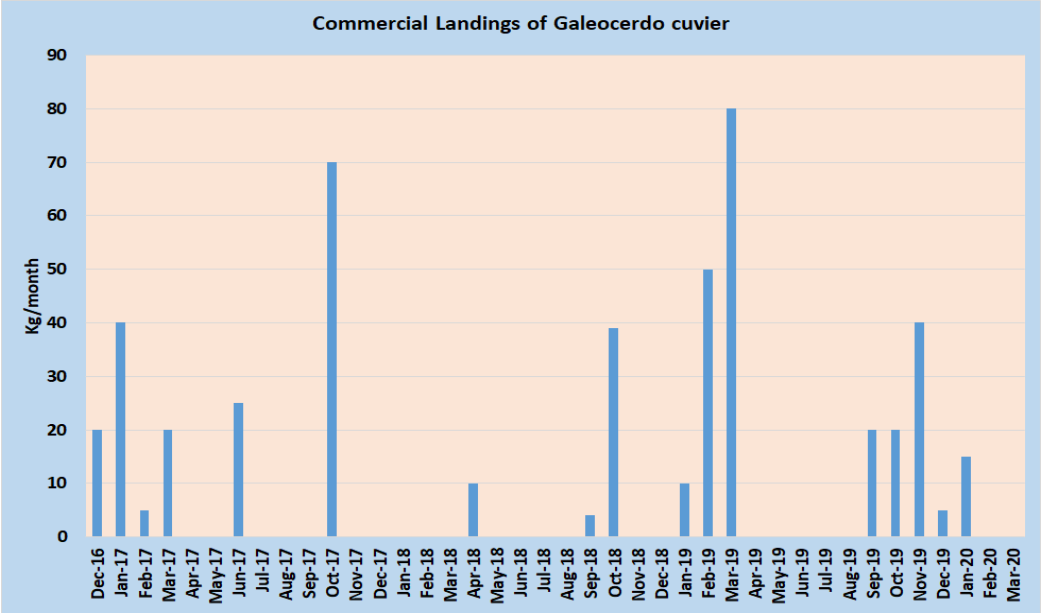

Fig. 13. Commercial landings of *Galeocerdo cuvier* at Karachi Fish Harbour.

Fig. 14. A large specimen of *Galeocerda cuvier* 339 cm TL caught on 11 October, 2019.

According to Cortés (1999), food of tiger shark consists of decapod crustacean (12.2 %), benthic invertebrates (0.2 %), molluscs (0.6 %), mammals (4.6 %), sea turtles (23.8 %), sea bird (10.4 %), teleosts (35.4 %), chondrichthyes (8.0 %) and squid/cuttlefish (4.8 %). Bowman *et al*. (2000) reported stomach content of tiger sharks from northwest Atlantic Ocean consisting of sea turtles (7.60 %), mammals (30.1 %), sea bird (0.2 %), teleosts including bluefish, goosefish, Atlantic mackerel, scup, cod and gurnards (37.6 %), chondrichthyes including tiger shark, dusky shark and basking shark. (20.0 %), squid/cuttlefish (0.3 %) and unidentified (4.2 %). Randall (1967)

reported the food of tiger shark at Puerto Rico consisting of loggerhead turtle (*Caretta caretta*)-5 % and *Diodon hystrix* & *Monacanthus* (50%).

There are a number of other studies which indicates food of tiger sharks from various parts of the world. Being a voracious feeder, tiger shark has been of interest for scientists for determining its food and feeding habit. Lowe, *et al.* (1996) has studies the food of tiger shark from Hawaii consisting of surgeonfish, trumpet fish, triggerfish, jack, conger eel, dolphin fish, sailfish, wrasse, goatfish, flatfish, boxfish, damselfish, parrotfish, tuna, barracuda, pufferfish, sting rays, sharks, dolphins, spiny lobster, shrimps, cuttlefish, squid, crab, , green turtle (*Chelonia mydas*) as well as dog (*Canis familiaris*), cat (*Felis catus*), goat, mongoose (*Urva edwardsii nyula*), horse, sheep, rats and even human remain. Heithaus (2001) observed dugong (*Dugong dugon*) in the diet of from Australia. da Silva Monteiro (1998), Froese and Pauly (2022), Randall (1980, 1992), Wetherbee, *et al.*, (1990) and Winfield (1992) also provided information about the stomach content of tiger sharks. Smith (1997) reported that tiger shark can also feeds on carrion and garbage, including cans, pieces of metal and burlap bags.

Fig. 15. Juvenile *Galeocerda cuvier* .

Like other shark, tiger shark is also an ovoviviparous species. Males of tiger shark may attain sexual maturity at a size of 226-290 cm TL, while females mature at a length of 250-325 cm TL (Compagno *et al*. 2005). The gestation period ranges from 13 to16 months and female can give birth to 10 to 82 pups (Simpfendorfer 2009; Smith, 1997). Length of pups may range between 51 and 104 cm TL (Compagno, 1984; Compagno and Niem, 1998; Myers, 1991). A few females dissected at Ormara (Balochistan coast) during 1983 to 1985 contained 28 to 75 pups, depending on the size of female. During present study, however, no female with pups was examined.

Tiger shark is not known to have any specific locations as nursery areas (Cambra *et al*., 2021; Driggers, *et al*., 2008; Holland *et al*., 2019; Holmes, 2015; Whitney and Crow, 2007). Parturition in *G. cuvier* is believed to take place at many locations in its distribution range (Driggers *et al*., 2008; Holmes, 2015; Whitney and Crow, 2007), however, there are evidences that Hawaii and Bahamas and some other islands are preferred pupping habitats (Papastamatiou *et al*., 2013; Sulikowski *et al*., 2016). Cambra *et al*. (2021) reported a neonate of tiger shark (55 cm TL) using Baited Remote Underwater Video Stations (BRUVS from Cocos Island National Park which is an oceanic island in the Eastern Tropical Pacific Ocean indicating that this island may be a pupping area. No pupping grounds are known in Pakistan coast but juveniles are frequently caught in coastal waters on the shelf area and bays along the coast of Pakistan (Fig. 15).

Wintner and Dudley (2000) reported growth parameters for tiger sharks from east coast South Africa. According to them asymptotic length (L_∞) was calculated to be 301 cm TL with a growth coefficient (k) to be 0.202 year^{-1} and age at 0 length (t_0) to be 1.11 year^{-1}. Branstetter *et al.* (1987) studied the growth parameters of tiger shark population in the Gulf of Mexico and the Atlantic Ocean and noted difference in various parameters. They observed that sexes combined growth parameter estimates for the Gulf of Mexico population were L_∞ = 338 cm TL, k = 0.184, t_0 =-1.13 year^{-1} and for Atlantic population these parameters were L_∞ = 440 cm TL, k = 0.107, t_0 =-2.35 year^{-1}. Male mature at approximately 310 cm TL and female at 315-320 cm TL. In Gulf of Mexico, male mature in 7 years and female whereas male 8 years whereas in the Atlantic Ocean both male and female mature in approximately 10 years. Branstetter *et al.* (1987) further observed that tiger shark grow rapidly as compared to other species of shark.

Marketing: There is specific market for tiger sharks in Pakistan. Its meat, like meat of other sharks, is consumed locally whereas its fins are exported to Hong Kong. There is no restriction on catching, landing and marketing of this shark, therefore, there is no restriction on export of its fins. Its offal is dried and used as a raw material for fish meal.

Specific Conservation Measures: No information about stocks of tiger shark in Pakistan is available, however, noticeable reduction in the catches of this species is reported during last 40 years. Tiger shark is not currently legally protected in any part of its range. There is no management regime in place for conservation and protection of the stocks of this species in Pakistan and in the regional countries. Tiger shark is assessed globally under IUCN Red List as Near Threatened (NT). It is not evaluated by CMS and CITES. It is considered as highly migratory species and included in the Annex I of the 1982 Convention on the Law of the Sea (FAO Fisheries Department, 1994).

Tiger shark is consider to be sensitive to fishing pressure due to a patchy distribution, considerable reduction in the catches in past two decades and late age at maturity, therefore, there is a need for development of a management plan for tiger sharks restricting or putting a ban on catching, landing and marketing in Pakistan.

Negaprion acutidens (Rüppell 1837)
(Fig. 16-18)

Fig. 16. *Negaprion acutidens*

Habit and Habitat: This species is commonly known as sicklefin lemon shark (Fig. 16) that inhabits up to a depth of 92 m. In Pakistan (both in Sindh and Balochistan) it is called "ham" or "safaid ham". This species is mainly inhabitant of continental and insular shelves and terraces. It is also known to occur in coral reefs areas as well as in lagoons, and mangrove swamps (Compagno *et al*., 1989; Last and Stevens, 1994). It is a sluggish shark that tends to swim slowly along the bottom, with frequent rest periods on the substrate. However it is occasionally observed near the surface, especially when tempted by potential prey.

The sicklefin lemon shark is known to distributed mainly in the Indo-Pacific area including Red Sea, East Africa, South Africa, Seychelles, Madagascar, Mauritius (Mascarenes) and Persian Gulf east to Marshall Islands and Society Islands, north to Ryukyu Islands, south to Rottnest Island (Western Australia), Queensland (Australia), Chesterfield Islands, Palau, Marshall Islands, Tahiti and New Caledonia (Froese and Pauly, 2022). It is also recorded from Taiwan (Shao et at., 1992).

Seasonal Distribution : The sicklefin lemon shark used to commonly occurring demersal sharks being landed in the Karachi Fish Harbour and other landing centres, however, its landings has considerably decreased and now seldom recorded. Although no distinct seasonal pattern of landings of *Negaprion acutidens* was observed but it was observed to be in landed in 21 months out of 39 months study period (Fig. 17). Highest monthly landings of 50 kg was recorded in September, 2019 whereas in June, 2017 monthly landings was reported to be 41 kg. This species was landed throughout the year in 2017 except in July and September. Since there is no aimed fisheries for sharks in Pakistan since last 2 decades, therefore, landings are based on bycatch of fisheries such as trawling, gillnetting and longlining in the coastal area over the shelf.

Biological Aspects: It is reported to achieve a maximum length of 380 cm (Fischer, *et al*. 1990). A specimen measuring 275 cm TL was landed in Karachi Fish Harbour on 16 April, 2014 whereas large specimens exceeding 150 cm TL are frequently landed at Karachi Fish Harbour and other landing centres.

The sicklefin lemon shark feeds on teleosts and small chondrichthyes (Compagno *et al*., 1989). During present study only two *Negaprion acutidens* were dissected which indicates that it feeds mainly on teleosts and cephalopods. The stomach content included greater lizardfish (*Saurida tumbil*), rough flathead (*Grammoplites scaber*) and barface sandsmelt (*Parapercis nebulosi*) and semi-digested fish and cuttlefish (*Sepia sp*.). Cortés (1999) reported that its food consists of decapod crustaceans (8.50 %), molluscs (2.40 %), benthic algae/weeds (1.10 %), teleosts (84.40 %)

and squids/cuttlefish (3.60 %). Salini *et al*. (1992) reported that food of sickle lemon fish (64.80 cm TL) from offshore, Albatross Bay, Australia to be entirely of pelagic molluscs. They have also reported that food of a *Negaprion acutidens* (80.50 cm TL) consisted of shrimps/prawns (0.20 %) and teleosts (99.8 %).

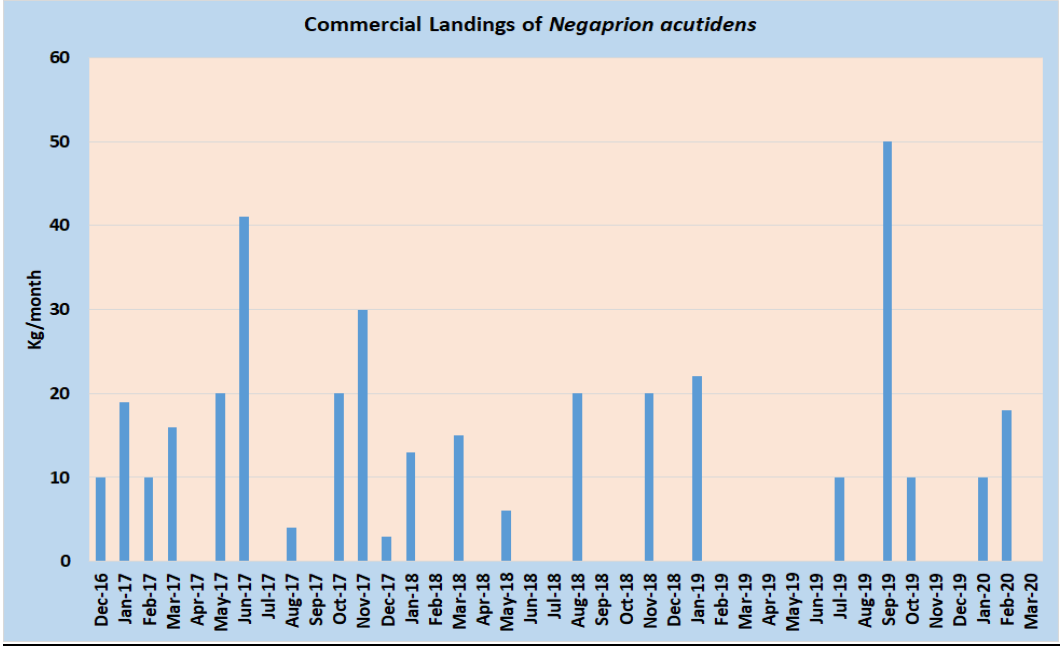

Fig. 17. Commercial landings of *Negaprion acutidens* at Karachi Fish Harbour.

Negaprion acutidens is a viviparous species (Dulvy and Reynolds, 1997) which gives birth to 1-14 pups per litter. The pups are 45 to 80 cm TL long (Myers, 1991; White *et al*., 2006) which are born following a gestation period of 10-11 months (Compagno *et al*., 1989; White *et al*., 2006). During the present study, a number of females from sicklefin lemon shark were dissected but only one female has a fully matured pup having a length of 63 cm (Fig. 18).

Fig. 18. Foetus of *Negaprion acutidens* dissected from a female landed at Karachi Fish Harbour.

According to Weideli *et al.* (2019) the maturity is attained by this species at total lengths ranging from 220-240 cm for both males and females. The growth rates in *N. acutidens* was observed varied from 0.2 to 28.2 cm $year^{-1}$ in individuals captured as neonates and from 0.8 to 32.2 cm $year^{-1}$ (14.9 ± 1.5 cm $year^{-1}$; $n = 31$) in individuals captured as juveniles. Freitas, *et al*. (2006) observed mean growth rates in lemon sharks (*Negaprion brevirostris*) were 24·7 cm year− 1 in total length, however, noted no significant difference in growth rates between males and females. According to Hodgkiss *et al.* (2017) mean annual growth rate in sicklefin lemon shark was 5.40 cm y–1 and a mean size at birth of 62.5 cm TL.

Marketing: There is specific market for sickle lemon sharks in Pakistan. Its meat, like meat of other sharks, is consumed locally whereas its fins are exported to Hong Kong. There is no ban on catching, landing and marketing of this shark, therefore, there is no restriction on export of its fins. Its offal is dried and used as a raw material for fish meal.

Specific Conservation Measures: No information about stocks of *Negaprion acutidens* in Pakistan is available, however, noticeable reduction in the catches of this species is reported during last 40 years. The sicklefin lemon shark is not currently legally protected in any part of its range. There is no management regime in place for conservation and protection of the stocks of this species in Pakistan and in the regional countries. According to IUCN Red List, this species is assessed as globally as Vulnerable (VU). It is not evaluated by CMS or CITES. Restricted distribution, slow growth rate, limited fecundity, patchy distribution, low abundance, late age at maturity and habitat preference make this species sensitive to fishing pressure, therefore, there is a need for development of a management plan for sicklefin lemon shark. This plan may ensure restricting or putting a ban on catching, landing and marketing in Pakistan. There is some evidence of local extinctions off the coasts of India and Thailand whereas there is major reduction in landings of this species in Pakistan.

Stegostoma fasciatum (Hermann 1783)
(Fig. 19-21)

Fig. 19. *Stegostoma fasciatum*

Habit and Habitat: The zebra shark is also large bodied, inshore shark (Fig. 19), found on the continental and insular shelves (Compagno, 1984). In Sindh, it is called "billi", "poonshrin" or "kori" and in Balochistan it is known as "pishi" or "goj". The zebra shark is found in the tropical waters of the Indo-Pacific region, from South Africa to the Red Sea and Persian Gulf (including Madagascar and the Maldives) to, Pakistan, India and southeast Asia (including Indonesia, the Philippines and Palau), northward to Taiwan and Japan, eastward to Taiwan and Japan, eastward to New Caledonia and Tonga, and southward to northern Australia (Compagno, 1984, 2001). It is found up to a depth of 90 m (Weigmann, 2016) but more common between 5 and 30 m (Myers, 1991). Genetic data has revealed two distinct subpopulations; "Indian- Southeast Asian", and "Eastern Indonesian-Oceania subgroup" (Dudgeon *et al*. 2009). This is likely due to a strong site fidelity to the reefs individuals reside at. Though individuals do migrate seasonally within a limited range (Dudgeon *et al*., 2013). Zebra shark is usually sluggish during daylight hours, becoming active to hunt nocturnally (Compagno, 1984). It is often observed sitting on the bottom in close proximity to coral reefs. The zebra shark is known to occur in the coral assemblages at Astola and Churna Islands along Balochistan coast. Its presence and distribution in Pakistan is described by Moazzam and Osmany (2021).

Seasonal Distribution: There is no distinct seasonal pattern of landings of zebra shark in Karachi Fish Harbour as it is seldom landed at Karachi Fish Harbour (Fig. 20). It is observed to be landed in 7 months out of 39 months study period. Highest monthly landings of 50 kg was recorded in March, 2017 whereas in March, 2020 monthly landings was reported to be 15 kg and remaining six occasions its landings was 10 kg per month or even less. It may be pointed out that there is no aimed fisheries for sharks in Pakistan since last 2 decades, therefore, landings are based on bycatch of fisheries such as trawling, gillnetting and longlining in the coastal area over the shelf.

Biological Aspects: This is considered to be large shark achieving a maximum length of 246 to 280 cm TL (Dudgeon *et al*. 2008; Randall *et al.*, 1990). A specimen measuring 266 cm TL was landed in Karachi Fish Harbour on 17 May, 2013 whereas large specimens exceeding 220 cm TL are frequently landed at Karachi Fish Harbour and other landing centres. Males attain sexual maturity at 150–180 cm (TL), and females at 170 cm TL (Compagno, 2001). The lifespan of the zebra shark is believed to be 25-30 years. Zebra sharks are strong and agile swimmers, propelling themselves with pronounced anguilliform undulations of the body and tail (Compagno, 2001).

During the study period, no stomach content of zebra shark was examined, however, this species primarily feed on benthic animals. According to Cavanagh *et al*. (2003) and Kyne *et al*. (2005) natural food of zebra shark may consist of gastropod, bivalve molluscs, crabs, shrimp, and small fishes. The slender, flexible body of this shark allows it to wriggle into narrow holes and crevices in search of food, while its small mouth and thickly muscled buccal cavity allow it to create a powerful suction force with which to extract prey (Compagno, 2001).

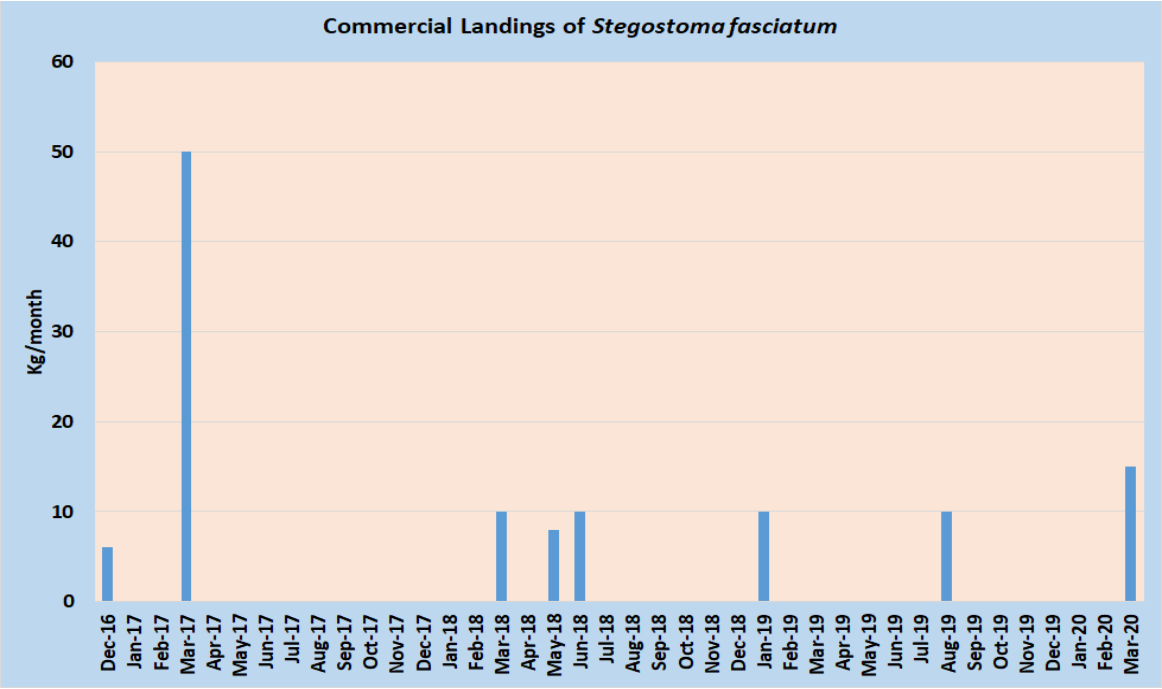

Fig. 20. Commercial landings of *Stegostoma fasciatum* at Karachi Fish Harbour.

According to Cortés (1999) its food consists of molluscs (100 %) whereas Allen (2004) reported that zebra shark feeds on gastropods and small bony fishes. crab, shrimps/prawns, clams, gastropods and octopi are included in food items of zebra shark (Compagno *et al*., 1989). Masuda and Allen (1993) reported that in the Indo-Pacific area, zebra shark feeds on unidentified benthic crustaceans, fishes and molluscs.

Zebra shark is an oviparous species (Compagno 1984; 2001; Dulvy and Reynold, 1997) Its egg cases are large, dark brown or purplish black, with longitudinal striations (Last and Stevens, 1994). Egg cases are 17 cm long, 8 cm wide and about 5 cm thick and has hair-like fibers along the sides with which it secure to the substrate (Compagno, 2001). Females have been documented laying up to 46 eggs over a 112-day period *(*Kunize and Simmons, 2004). Eggs are deposited in batches of around four. Size at birth was reported to 20-26 cm TL (Compagno, 1998).

The colour pattern in young zebra sharks is dark brown above and light yellow below, with vertical yellow stripes and spots (Fig. 21). As the shark grows to 50–90 cm, the dark areas begin to break up, changing from light-on-dark stripes to dark-on-light spots (Compagno, 2001). The stripes of the juveniles may be an adaptation against predator, making each individual in a group harder to target. There have been reports of female zebra sharks producing young asexually whereas parthenogenesis was observed in females *(*Dudgeon, *et al.*, 2017; Robinson *et al*., 2011).

Marketing: There is specific market for zebra sharks in Pakistan. Its meat is considered to be of bad taste, therefore, this species is generally not liked. In most cases, this species is discarded and thrown overboard. Its fins are, however, exported to Hong Kong. There is no restriction on catching, landing and marketing of this shark, therefore, there is no restriction on export of its fins. Its offal is dried and used as a raw material for fish meal.

Specific Conservation Measures: No information about stocks of zebra shark in Pakistan is available, however, noticeable reduction in the catches of this species is reported during last 40 years. There is no management regime in place for conservation and protection of the stocks of this species in Pakistan and in the regional countries. Under IUCN Red List, zebra shark is assessed as globally as Endangered (EN). It is not evaluated by CMS or CITES.

Globally declines in populations have been noticed which is attributed to increased inshore fishery activities and coral reef habitat loss (Pillans and Simpfendorfer 2003). Major threats to this species include overfishing as bycatch of trawl fisheries, habitat destruction, patchy distribution, low abundance, late age at maturity and coastal development, particularly of mangrove forests which are utilised by juveniles, therefore, there is a need for development of a management plan for zebra sharks restricting or putting a ban on catching, landing and marketing in Pakistan.

Fig. 21. Zebra shark juvenile.

CONCLUSIONS

Demersal sharks are important component of the marine ecosystem especially in the inshore waters over continental shelf and slope in Pakistan. Like pelagic sharks, these elasmobranchs are usually top predators in the demersal food chain and play important role as production dynamics in coastal and offshore waters. In Pakistan, large demersal sharks are mainly caught as bycatch by a large fleet of bottom-set gillnetters and longliners that operate in coastal waters. Additionally large demersal sharks are also caught by pelagic gillnets and trawl nets as bycatch. Presently there is no aimed fisheries for large demersal sharks. The aimed fishery for demersal sharks using bottom-set gillnets (multi-monofilament) and bottom-set longlines during 1986 and 2000. In addition, there used to be a reasonably large handline fisheries based mainly in Ormara and Jiwani prior to 2000. Large hooks, most of them locally made, are employed for the purpose. Meat of eels and stingrays were main bait used for sharks. In the handline fisheries, live bait (saddle grunt-*Pomadasys maculatus*- locally known as "tantar") were mainly used, however, when large demersal sharks were to be targeted sometimes meat of other marine animals was also used (Kiani and Waerebeek, 2015). Fishing for these large demersal sharks with such handlines used to be done at depth of 100 to 300 meters.

There are 6 species of large demersal sharks that are caught and landed by the fishing vessels in Pakistan. Meat of all sharks is locally consumed and fins are dried and exported to Hong Kong whereas offal is dried and used as raw material for fish meal. Meat of zebra shark is considered to be of poor quality, therefore, fetches low prices. Most zebra sharks are, therefore, discarded at sea or used as a raw material for fish meal. None of the large demersal shark species are included in Appendix-II of the CITES, therefore, it is not illegal to export their fins. The fins of large demersal sharks are, however, exported from Pakistan as dried fish.

Bull shark (*Carcharhinus leucas*) was observed to be the most common species of large demersal sharks followed by spinner shark (*Carcharhinus brevipinna*) and then by pigeye shark (*Characharhinus ambionensis*). Sicklefin lemon shark (*Negaprion acutidens*) used to among common occurring species but now seldom caught. Similar reduction has been found in these landings of tiger shark (*Galeocerda cuvier*) and zebra shark (*Stegostoma*

fasciatum). Present landings of even bull, spinner and pigeye sharks are considerably less than their catches during 1980's and 1990's which is attributed to large scale targeted fishing for sharks during 1990's using bottom-set longlines and gillnets. It may be added that there is no legal cover available for protection of large demersal sharks under fisheries legislation of the country. Unlike most pelagic sharks including silky, oceanic whitetip, thresher and hammerhead sharks whose catching, retention, marketing and trade pelagic sharks is banned under the provincial (Sindh and Balochistan) fisheries legislations, no such legislation is promulgated for large demersal sharks. Considering that there is a major decrease in the landings of large demersal sharks mainly due to extreme overfishing, there is an immediate need for enactments of laws at provincial (both Sindh and Balochistan) and federal levels for protection of these species.

Like all pelagic species (Moazam and Osmany, in press), large demersal sharks are observed to be top predator of the coastal and oceanic ecosystem and their conisderable removal through target or bycatch fisheries may alter ecological functioning which may lead to trophic cascade. In Pakistan, there was an aimed shark fisheries during 1990's which led to collapse of shark landing by 1999. During this period most species that grow to large sizes have disappeared or their numbers were reduced substantially. This was especially noticeable in case of tiger, pigeye, sicklefin lemon and zebra sharks as their landings have substially declined. Although the ancedotal infrmation about their landings is not avaiable and present catches are not adequately recorded but still there are evendences that landings of large demersal sharks has considerable reduced in last two decades. The impact of this reduction in the number of these top predators on the open-ocean ecosystem along Pakistan coast is not known.

Fecundity in most large sharks sharks is low as they produce a few pups (maximum 82 in case of tiger shark). Owing to lecithotropic vivipary with oophagy and uterine cannibalism and resultant low reproductive rate, most large demersal sharks are prone to overexploitation. In most cases esepcially in case of bull shark, pupping takes places in coastal areas including bays and mouth of the River Indus but demarcation of these areas has not been made, therefore, there is an immediate need to identify such pupping areas for large demesal sharks as well as areas which are nursery ground for these sharks and entact area specific protection measures which will ensure protection of juveniles which are prone of fishing operations in coastal waters. The need for creation of awareness among fishermen communities for protection of these sharks cannot be overemphasized as control of overfishing can be effectively implemented if fishermen are engaged in such efforts.

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