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Deep-sea fishing for chondrichthyan resources and sustainability concerns—a case study from southwest coast of India

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Elasmobranchs comprising sharks, skates and rays have traditionally formed an important fishery along the Indian coast. Since 2000, Indian shark fishermen are shifting their fishing operations to deeper/oceanic waters by conducting multi-day fishing trips, which has resulted in considerable changes in the species composition of the landings *vis- a-vis* those reported during the 1980's and 1990's. A case study at Cochin Fisheries Harbour (CFH), southwest coast of India during 2008-09 indicated that besides the existing gillnet–cum- hooks & line and longline fishery for sharks, a targeted fishery at depths >300-1000 m for gulper sharks (*Centrophorus* spp.) has emerged. In 2008, the chondrichthyan landings (excluding batoids) were mainly constituted by offshore and deep-sea species such as *Alopias superciliosus* (24.2%), *Carcharhinus limbatus* (21.1%), *Echinorhinus brucus* (8.2%), *Galeocerdo cuvier* (5.4%), *Centrophorus* spp. (7.3%) and *Neoharriotta pinnata* (4.2%) while the contribution by the coastal species such as *Sphyrna lewini* (14.8%), *Carcharhinus sorrah* (1.4%) and other *Carcharhinus* spp. has reduced. Several deep-sea sharks previously not recorded in the landings at Cochin were also observed during 2008-09. It includes *Hexanchus griseus, Deania profundorum, Zameus squamulosus* and Pygmy false catshark (undescribed) which have been reported for the first time from Indian waters. Life history characteristics of the major fished species are discussed in relation to the fishery and its possible impacts on the resource.

[Keywords: Deep-sea chondrichthyans, fishery, India, management, sustainability]

Introduction

In 2007, India was the second largest shark fishing nation preceded only by Indonesia[1]. In addition to the traditional fishermen who operate from catamarans and small motorized canoes using handlines and occasionally bottomset gillnets and drift gillnets, nearly 600 mechanized boats (overall length: 12 to 15 m) actively fish for sharks using long lines, hooks and lines and gillnets along the entire Indian coast[2].

Until the mid 1980's, elasmobranchs were considered as a high value by-catch in commercial fishery, but later increasing export demand for fins, meat and cartilage to the Southeast Asian countries, demand for dried salted meat and small fresh sharks in the local markets of Tamilnadu and Kerala and a good demand for high-quality liver oil has led to targeted fishing for sharks including whale shark (which was later banned in 2001 under Indian Wildlife (Protection) Act, 1972) and for *Centrophorus* spp. whose liver containing squalene and other components are of high pharmaceutical importance and yields high value in export market.

Despite having a great fishery and landings, studies on chondrichthyans from Indian waters are few and are mostly concerned with fishery, few taxonomy works, distributional records[3,4]. Studies on fishery are limited to a few species, groups or area[5,6,7]. Worldwide, the total known chondrichthyan species is 1193[8], while in Indian waters, 84-110 species of elasmobranchs have been listed[4,9] and is yet one of the least studied region with regard to diversity of the resources.

Chondrichthyans are vulnerable to over-exploitation. Globally, lack of accurate catch data (due to under-reporting, lack of by-catch recording, poor species identification and species wise catch data, illegal fishing etc.) makes assessment and management of chondrichthyan exploitation difficult, which is a major concern. This issue was addressed by Convention on International Trade in Endangered Species (CITES) in 1994 which requested contracting parties to collect biological and trade information on sharks taken in their fisheries. This was reiterated by FAO in 1999 by its adoption of International Plan of Action (IPOA) for Conservation and Management of sharks. At present only a few countries have management and monitoring programmes for chondrichthyans.

The present study is focused on the changing species composition in the shark fishery, emerging targeted fishery for deep-sea sharks and bycatch of chondrichthyans in the deep-sea shrimp trawlers in the southwest coast of India and the potential vulnerability of the resources.

Materials and methods

During January 2008 to June 2009, weekly surveys were made on species and size composition in the chondrichthyan landings at Cochin Fisheries Harbour (CFH), southwest coast of India (Fig. 1). Landings from drift gillnet–hooks & line units (DGN-handline), longliners and the deep-sea trawls were recorded separately. Species identification was made following[10,11,12]. Total length (L_T) measurements were recorded in cm (centimeter). Observations recorded are discussed in the context of changing species composition and catch trends as obtained from earlier literature.

Results

Fishery

The traditional artisanal shark fishery of India has shifted following modernization and mechanization of fishing craft, and the drift gillnet/long line fishing fleet comprising 32-45 feet LOA which operated on a daily basis for sharks during the 1980's and 1990's[13], have been replaced by crafts of 45-65 feet LOA presently. These larger boats now have a crew of 8-14 and conduct multiday targeted shark fishing using long lines, gillnets and hooks & lines, at a depth of about 100-1000 m. Each fishing trips normally extends for 12 to 30 days at sea with a minimum vessel speed of 6-8 knots and GPS is used for navigation. While the smaller units employ hooks ranging from 1000 to 2500, larger vessels use 2500 to 4000 hooks and fishes such as scads (*Decapterus russelli, Megalaspis cordyla*), tuna, sardine and squids are used as baits. For targeted deep-sea shark (gulper shark), fishing hooks no.7 and 8 are used and area of operation are commonly between 8° 30' N and 10° 30' N; and 75° 20' E and 78° 9' E, at a depth of about 300-1000 m, whereas for pelagic sharks and rays, these boats migrate all along the Indian coasts (Fig. 2.1). Most of the shark fishermen who venture into multiday distant water fishing are from Thoothoor and nearby areas of Kanyakumari district (Tamilnadu). These fishermen stop gulper shark fishing, when the demand and availability of food fishes increases or gulper sharks availability decrease and during rough weather of monsoon (June-August). Besides these boats, deep- sea shrimp trawlers also target oceanic tunas and sharks, whenever available using longlines.

During 2005- 2008, market value for gulper sharks (*Centrophorus* spp.) oil shark or *mullan* as known in landing centres (vernacular: having spines) increased steadily, which lead to boom in the deep-sea shark fishery at Cochin (Fig. 2.2). However the targeted fishery for deep-sea sharks at Cochin ended pre-maturely by early months of 2009, when the fishermen refrained from deep-sea fishing as a result of price fall by more than half probably due to the global economic recession resulting in a fall in exports as well as declining catch and catch rates. But occasional landings in trawls and long lines continue.

Fig. 1—Map showing study area

Fig. 2.1—General shark fisharylandings (Pelagic sharks)

Literature review revealed that during the 1980's and early 2000 the entire shark landings in the Cochin Fisheries Harbour occurred as by-catch in single day drift gillnet/hooks & line fleet operated at about 50 m depths[13,14,15]. By late 2000 this fleet expanded operations to relatively offshore waters (>100m depths) and conducted multiday fishing, resulting in landings of several large oceanic and deepsea shark species[6]. In the last 2 to 3 years occasional landings and minor fishery of deepsea sharks like, *Centrophorus* spp. and *Echinorhinus brucus* have transformed into a regular fishery. The emerging fishery for deep-sea sharks is very evident at Cochin which represents the entire west coast with effort from over 360 units based at Cochin and the crew mainly from Thoothoor and nearby villages. The trend of changing species composition in the shark fishery is probably similar in many other landing centres spread along the entire Indian coastline of about 8129 km. Besides a directed deep-sea shark fishery, large quantities of deep-sea chondrichthyans, with large number of juveniles, are also occurring in deep-sea shrimp trawl bycatch. The present day sharks landings along southwest coast are dominated by gillnet bycatch and targeted fishing followed by hook and lines, long lines and trawl bycatch.

Species composition

During the study period 2008-09, more than 45 shark species belonging to 20 families, namely, Alopiidae, Sphyrnidae, Stegostomatidae, Proscyllidae, Rhincodontidae, Odontaspidae, Lamnidae, Squalidae, Hemigaleidae,Hexanchidae,Centrophoridae,Triakidae ,Echinorhinidae, Carcharhinidae, Pseudotriakidae, Scyliorhinidae, Hemiscylllidae, Ginglymostomatidae, Etmopteridae and Somniosidae were recorded. In 2008, landings were dominated by *Alopias* spp. (24.9%), *Carcharhinus* spp. (22.5%), *Sphyrna lewini* (14.8%), *Centrophorus* spp. (6.1%) and chimaeras (4.2%). Maximum diversity was observed in Carcharhiniformes and in deep-sea sharks, Squaliformes with species such as *Centrophorus squamosus, C. atromarginatus, C.* cf. *granulosus*, *C.*cf. *moluccensis*, *C.* cf. *isodon, Centrophorus* sp., *Deania profundorum*, *Squalus mitsukurii, Squalus* spp.*, Etmopterus pusillus, E.* cf. *lucifer, Zameus squamulosus* and *Centroselachus crepidater* landed. Species such as *Hexanchus griseus, Heptranchias perlo* (Hexanchidae) *C. squamosus, D. profundorum* (Centrophoridae)*, C. crepidater, Z. squamulosus, Iago omanensis, Apristurus indicus, Cephaloscyllium silasi, Okamejei powelli* and the Pygmy false cat shark have not been recorded in the fishery at Cochin Fisheries Harbour earlier (Tables 1 and 2). However, occurrence of deep-sea sharks like *C .moluccensis* and *E.brucus*[16,17,18], *C.granulosus*[19] and *C. squamosus*[20] has been reported in the nearby artisanal deep-sea fish landing centres. Species such as *H. griseus, D. profundorum, Z. squamulosus* and Pygmy false catshark recorded during the period were new distributional records[21] and some possible new species were observed in the landings, indicating that more studies with regard to the diversity of the shark resources in the region are required.

The elasmobranch landings at Cochin during the 1980's comprised mainly of thirteen species of pelagic sharks such as *Carcharhinus melanopterus, C. macloti, C. brevipinna, C. limbatus, Rhizoprionodon acutus, R. oligolinx, S. lewini* and *Scoliodon laticaudus* of which except the last four species the rest formed a regular fishery[13]. Publications from 1980's reported 12 elasmobranchs[14] and another study reported 7 species of sharks in the fishery during 1988 [15]. Thirty species were listed in the commercial shark fishery at Cochin during 2000-2002[6] in which *C. limbatus, C. sorrah, C. melanopterus* and *R. acutus,* formed the major component and large size groups of the oceanic sharks such as *Alopias* spp. and *Galeocerdo cuvier* were reported along with occasional landings of deep-sea sharks like *E. brucus, C. moluccensis* and *C. granulosus.* During 2006-2007 the number of species recorded in the fishery increased with very large-sized oceanic sharks such as *C. limbatus*, *Alopias superciliosus* and deepsea species such as, *E. brucus* and *Centrophorus* spp. occurring in significant quantities[22]. During 2006-2007, frequent occurrence of a deepwater shark *E. lucifer* was also reported[22] which was recorded very rarely during the present study period. Deep-sea chondrichthyan landing during 2008-09 was mainly composed of bramble shark (*E. brucus),* followed by gulper sharks (*Centrophorus* spp.) and chimaera, *Neoharriotta pinnata*. The change in the species composition of the chondrichthyan fishery landings at Cochin is evident. The effects of increasing effort, multiday distant water fishing and targeted shark fishing are the probable reasons for this change (Table 3). In the present study more than 45 species of sharks were recorded which comprised coastal, oceanic-pelagic

Table 1—Chondrichthyans observed in landings of the deep-sea fleets* at Cochin Fisheries Harbour during 2008-2009

Species	Length range (L_T, cm)	Occurrence in landings	Depth range[¥]
Rhinochimaeridae			
1. *Neoharriotta pinnata*	55 -147	Common in DGN, DST and LL	150-500
2. *Rhinochimaera* sp.	145-147	Rare, DST	150-500
Alopiidae			
3. *Alopias pelagicus*	100-221	Common in DGN, H&L, LL	0-300
4. *A. superciliosus*	112-235	,,	0-500
Echinorhinidae			
5. *Echinorhinus brucus*	62 - 318	Common in DGN, H&L, DST, LL	10-900
Carcharhinidae			
6. *Galeocerdo cuvier*	106-140	Rare in DST, common in DGN-H&L and LL	0-371
Centrophoridae			
7. *Centrophorus squamosus*	58 - 107	Common in DGN, H&L, LL and DST	145-2400
8. *C. atromarginatus*	38 - 90	,,	183-450
9. *C.*cf. *moluccensis*	46- 90	,,	125-823
10. *C.*cf. *granulosus*	38-104	,,	50 - 1440
11. *C.*cf. *isodon*	46-87	Rare, LL	700-800
12. *Centrophorus* spp.,	60-66	,,	150-500
13. *Deania profundorum*	57-69	LL and DST	205 - 1800
Hexanchidae			
14. *Hexanchus griseus*	87 - 260	Rare, DGN	180-1100
15. *Heptranchias perlo*	80 -107	Rare, LL and DST	0-1000
Somniosidae			
16. *Centroselachus crepidater*	74-76	Occasional, LL and DST	230-1500
17. *Zameus squamulosus*	45	Rare, DST	
Etmopteridae			
18. *Etmopterus pusillus*	30.5-46.5	Rare, DST & LL	0-1070
19. *E.*cf. *lucifer*	38-43	,,	150-1250
Squalidae			
20. *Squalus cf. mitsukurii*	36-64	,,	29-600
21. *Squalus* spp.,	38-56	,,	100-500
Pseudotriakidae			
22. Pygmy false catshark	63	Single specimen	1120
Triakidae			
23. *Iago omanensis*	60-65	Rare -DST	110-2195
24. *Iago* spp.,	46-60	,,	250-450
25. *Mustelus* spp.,	89-96	Occasional, DGN, LL.	20-250
Scyliorhinidae			
26. *Apristurus indicus*	56	Rare, only in DST	1289 - 1840
27. *Cephaloscyllium silasi*	41-46	,,	300
28. *Bythaelurus hispidus*	15-20	,,	200-300
Proscyllidae			
29. *Eridacnis radcliffei*	12-22	Occurred only in DST	71-766
Rajidae			
30. *Okamejei powelli*		Rare, DST	17-462
31. *Dipturus johannisdavisi*		Rare , only in DST	410 - 549
32. *Dipturus* sp.		,,	100-800

*includes species observed in targeted deep-sea shark fishing as well as bycatch in deep-sea shrimp trawls.(DGN- drift gillnet, LL- long line, HL- Hook & line, DST- Deep-sea shrimp trawler) [¥] Ref. 29

Table 2—List of shark species occurring occasionally/rarely in the landings*

Family	IUCN Red list status, 2009
Hemigaleidae	
1. *Chaenogaleus macrostoma*	Vulnerable
2. *Hemipristis elongata*	"
Carcharhinidae	
3. *Carcharhinus macloti*	Near threatened
4. *C. falciformis*	"
5. *C. albimarginatus*	"
6. *C. amblyrhynchos*	"
7. *C. amboinensis*	Data deficient
8. *Negaprion acutidens*	Vulnerable
9. *Prionace glauca*	Near threatened
10. *Triaenodon obesus*	,,
Sphyrnidae	
11. *Sphyrna mokarran*	Endangered
12. *Sphyrna zygaena*	Vulnerable
Hemiscyllidae	
13. *Chiloscyllium griseum*	Near threatened
14. *Chiloscyllium arabicum*	"
Ginglymostomatidae	
15. *Ginglymostoma cirratum*	Data deficient
16. *Nebrius ferrugineus*	Vulnerable
Rhincodontidae	
17. *Rhincodon typus*	Vulnerable
Odontaspididae	
18. *Odontaspis ferox*	Vulnerable
Lamnidae	
19. *Isurus oxyrinchus*	Vulnerable
20. *Lamna nasus*	"

<1% contribution to shark fishery at Cochin

species as well as the deep water species and few species still unidentified.

Length frequency

Biological studies on sharks of the Indian EEZ are very limited and that on deep sea sharks are meager. Among the emerging fisheries, *C. atromarginatus, C. squamosus* and *E. brucus* were the major species landed with a size range of 38-90, 58-107 and 62-318 cm TL respectively. While huge quantity of *N. pinnata* in the size range of 55-147 cm TL were observed in the fishery (Fig. 3). Reports say that in elasmobranchs, the length at first maturity (L_m) is attained approximately at 75% of maximum length of

Fig. 2.2—Deep-Sea shark fishery landing

Table 3—Species composition (% shark landings) at Cochin Fisheries Harbour*

Species	1981-82[1]	1986- 87 [2]	2000-02[3]	2006 -07[4]	2008[#]	Depth range[¥]
S. lewini	26-31	27.1	9.1	11	14.8	0-512
C. limbatus	NA	24.5	31	29.7	21.1	0-64
C. sorrah	NA	11.1	13	0.2	1.4	0-140
C. hemiodon	NA	3.7	NA	0.8	NA	0-100
C .longimanus	NA	4.2	1.7	0.1	NA	0-230
C. brevipinna	1.4-3	NA	6.7	0.002	NA	0-100
C. leucas	NA	3.6	NA	0.1	NA	1-152
C. macloti	2.2-2.3	NA	NA	NA	NA	170
C. melanopterus	31.7-33.8	NA	18	NA	NA	20-75
Centrophorus spp.,	NA	NA	NA	12.3	6.1**	50-2400
A. vulpinus	NA	0.1	3.6	0.8	NA	0-550
A. pelagicus	NA	NA	9	NA	0.7	0-300
A. superciliosus	NA	1.7	NA	23.9	24.2**	0-500
G. cuvier	NA	NA	NA	0.8	5.4**	0-371
S. laticaudus	4.7-8	2.7	NA	0.2	NA	10-13
R. acutus	23-26	15.4	1	0.9	0.9	1-200
S. fasciatum	NA	4.6	NA	0.3	5.3	0-63
E. brucus	NA	1.2	NA	17.2	8.2**	10-900
N. pinnata	NA	NA	NA	1.3	4.2**	150-500
R. oligolinx	1.7-2.7	NA	NA	NA	NA	0-36

Sources: 1- Ref .13; 2 & 4 – Ref. 22, 3- Ref. 6 (only longline); #- Vivekanandan (In prep.); * *N. pinnata* is also included; ** occurred in significant quantities as related to 80s period; [¥] Ref. 29; NA- Data not available /contributed very little to fishery

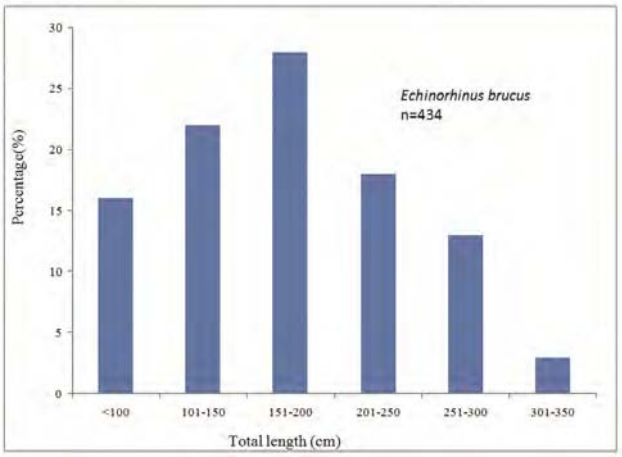

Fig. 3.1

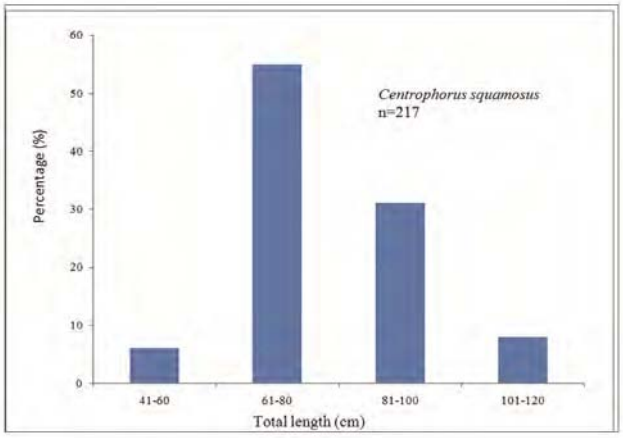

Fig. 3.2

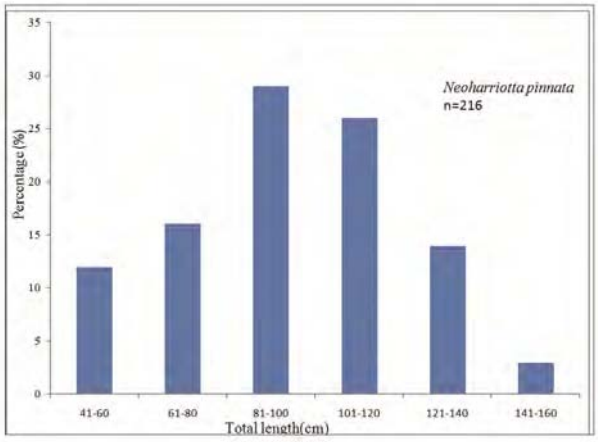

Fig. 3.3

Figs 3.1, 3.2 & 3.3—Length class (%) in the observed landings

the species[23]. The L_m of females of *C. squamosus* and *E. brucus* is thus reported to be 137 and 200 cm respectively[8]. Based on the length frequency distribution, the entire landings of *C. squamosus* are thus composed of juveniles while for *E. brucus* nearly 63% of the numbers landed are immature. However, most of the landings of *N. pinnata* are above its estimated L_m of 96 cm. Fecundity/ovarian fecundity count of some deep-sea shark species observed in the landings were very few compared to pelagic species eg., *Heptranchias perlo* (6-7 mature oocytes, 58-61mm), *E. brucus* (10-33 mature oocytes, 62-76 mm), *C.*cf. *granulosus* (1-3 mature oocytes, 60-78 mm) and *Eridacnis radcliffei* (1-2 embryo) which makes them highly vulnerable.

Processing & Utilization

Shark fishery is mainly driven by market value for fins, which fetches good price in the export markets of Southeast Asian countries like Singapore, Thailand, Taiwan, Malaysia, China and Hongkong. Shark fins are usually sent to Chennai to be exported. Small sharks in fresh condition are used for food preparation in households, and in certain parts of Kerala, ray food items are used for ceremonial functions and gatherings. Filleted, salted & dried shark meat is another important product which has a wider acceptance in states of Karnataka, Tamilnadu & Kerala (Figs 4.1, 4.2 & 4.3). Shark jaws are also sold or exported. Only a few selected sharks' skins are used for tanning. There is a small developing demand for shark cartilage. The targeted deep-sea shark fishery is driven by high market demand of squalene rich liver oil from gulper sharks (*Centrophorus* spp.), livers will be removed manually at nearby processing centres which is chopped into smaller pieces and oil is extracted using machine or by cooking. Crude liver

Fig. 4.1—Salted & dried shark meat for sale

Fig. 4.2—Drying deep-sea shark fins for export

Fig. 4.3—Sun drying of shark fins, jaws and skin

oil is kept in large barrels and distributed to pharmaceutical companies or sold to exporters. Deepsea shark meat also used in salted dried form. Though targeted deep-sea shark fishing brings many other chondrichthyan species (Table 1), most of them are not used for liver oil preparation because of their low oil content and quality. Other than *Centrophorus* spp. deep-sea sharks like *E. brucus* and *H. griseus* are also sold at comparatively higher prices because of its large liver and meat quantity. Market values for deepsea shark fins are lower compared to pelagic sharks.

Discussion

Targeted fishery for gulper sharks/oil sharks from Indian waters have emerged recently and must be viewed with concern, since these deep-sea chondrichthyans are highly vulnerable to overfishing[24,25]. Several species presently landed are mostly caught from depths up to 150 m while *Centrophorus* spp. is targeted from deeper waters. It has been reported that several species of dogfishes (*Centrophorus* spp.) that inhabit water of the upper continental slope (200-600 m) are at particularly vulnerable to overfishing as they are fished throughout their distribution range and dominant portion of catch are females.

During 2000-2002 the contribution of deep-sea/demersal chondrichthyans in the fish landing at Cochin was negligible and didn't contribute much to the total landings. Before 2000 these species occurred only as incidental landings and were very rare. Later the contribution of these species in the fishery increased significantly to reach an all time reported peak in 2006-07 with deep-sea elasmobranchs contributing over 50 % to the observed shark landings at Cochin. This change in species composition may be attributed to increase in mechanization of craft and modernization of gear, extension of fishing grounds to oceanic and deeper waters and a possible decline in the coastal shark stocks due to heavy exploitation. In the year 2008 also deep-sea chondrichthyans contributed a major share to the total shark landings but showed a slight decrease from the previous year with 38.5 % of the shark landings at Cochin.

Chondrichthyans are generally considered to be K-selected as they are relatively slow growing, mature late and have low reproductive output. Based on their varied life history attributes such as age at maturity, annual litter size, natural mortality and proportion of population surviving to maturity etc., their productivity (ability to sustain fishing pressure / recover from overfishing) has been estimated[8] but still information is lacking for many groups especially for the deeper water species. Since sharks are high trophic level in the oceans any decrease in their stocks will have great effects on the whole trophic system. Catch decline due to targeted fisheries for gulper sharks in several countries of Indian Ocean such as Maldives has been reported[26]. Studies have proven that when shark stocks are exploited beyond the sustainable level it takes years to recover and establish[23, 24].

It is expected that due to high market value of the shark products in the international market [27] fishing pressure on these resources are likely to increase. A Markov Chain Analysis of the landings of the region has revealed that shark landings which ranked 50 during the year 2005 are expected to reach between 21 to 25 positions within a few years[28]. Few studies

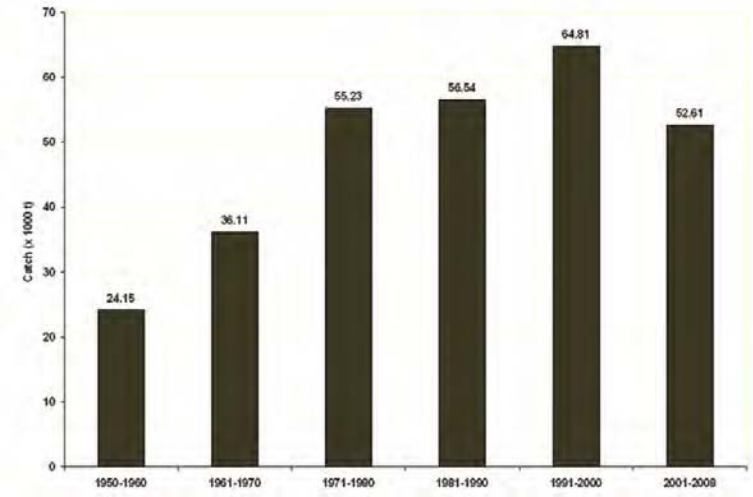

Fig. 5—Average all India decadal landings of chondrichthyans

have been undertaken to determine the biological characteristics of the fishery species as well as its sustainability. In view of the open access and largely unregulated exploitation of Indian marine capture fisheries, targeted exploitation of vulnerable resources like elasmobranchs especially deep-sea sharks needs to be continuously monitored and detailed studies on fishery and biological aspects of the major species are required.

The decreasing trend of the estimated chondrichthyan landings along the Indian coast (average: 60,000 t during 1990s and 48,000 t during 2006-08, Fig. 5)[30,31] also points to the need for a comprehensive action plan/policy for a sustainable elasmobranch fishery with due consideration for the livelihoods of the fishermen.

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