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Diversity, abundance and size structure of pelagic sharks caught in tuna longline survey in the Indian seas

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Diversity and abundance of pelagic shark bycatch in the tuna longline operations in northern Indian Ocean were examined for the period 2004-2010. During the survey 1.2 million hooks were deployed in three regions of seas around India resulting in the catch of 1501 numbers of sharks. Significant variations in the diversity and abundance of pelagic sharks were observed among the three regions of Indian seas. Catches of sharks are prominent in Andaman & Nicobar region contributing 35.15% of the catch by number and 51.46% by weight. In the eastern Arabian Sea, sharks constituted 15.49% and 14.89% of the total catch by number and weight respectively. In western Bay of Bengal, this group contributed 7.74% (by number) and 9.33% (by weight) to the total catch. *Alopias pelagicus*, *Carcharhinus limbatus*, *Alopias superciliosus* and *Carcharhinus falciformis* were the dominant species of pelagic sharks observed in the Indian seas. Time series analysis of hooking rates revealed drastic decline in the abundance of pelagic sharks in the Arabian Sea as well as Bay of Bengal.

[Keywords: bycatch, hooking rate, Arabian Sea, Bay of Bengal, Andaman & Nicobar waters, sex ratio, length-weight relationship]

Introduction

Sharks play an important role in maintaining stability of the marine ecosystems, since they function as apex predators and scavengers, exerting significant impact on other components of the marine ecosystems[1,2]. They form the major bycatch of pelagic longline fishery targeting high value tunas and swordfish. Until recently, sharks were non-target species in the pelagic longline fishery, and they were mostly discarded or released at sea[3]. However, globalization and development of new markets, world wide spread of eastern restaurants, and economic boom, especially in several Asian nations during 1990's, resulted in increased demand for shark fins and flesh. As a result, the shark mortality rates raised alarmingly, killing more than 80% of the sharks caught during fishing operations[4] and the global catches of sharks, rays and chimaeras increased from about 2,41,113 t in 1950 to 7,38,924 t in 2010[5].

In the Indian seas, longline fishery is mainly targeting yellowfin and bigeye tunas. As reported elsewhere[6-8], the bycatches, especially sharks constitute a major portion of the longline catch in the Indian waters also. In order to evaluate the impact of longline fishery on pelagic sharks, and thereby evolve suitable measures or fishing policies to protect them, it is essential to identify and quantify the catch and mortality of this ecologically and economically important group. Further, analysis of trends in the abundance indices for appreciable period of time can indicate the status of fish populations[9].

The diversity, spatio-temporal distribution and biomass of pelagic shark bycatch in longline fishery from the seas around India are poorly studied, except few studies carried out mainly by Fishery Survey of India (FSI)[10-15]. Species-wise landing of shark is usually unavailable in official statistics as different species are aggregated as "sharks". This may result in masking basic changes in community structure and profound changes in populations of the larger, slower growing species[16]. Fishery independent abundance data from exploratory surveys are preferred over commercial fishery data since they do not have many of biases including changing fishing grounds, gears, methods and targeting practices[9]. With this perspective, we studied the impact of longline fishery on the pelagic sharks in the seas around India and the present paper is aimed to give an update on the catch composition, species diversity, trends in relative abundance and length–weight structure of some important species of pelagic sharks occurring in Indian seas.

Materials and Methods

Data on the nominal catch of sharks recorded during the tuna longline survey conducted by four longliners of FSI (*Matsya Vrushti*, *Yellow Fin*, *Matsya Drushti* and *Blue Marlin*) during the period from January 2004 to December 2010 are used in this study. These four vessels were deployed respectively from Mumbai, Mormugao, Chennai and Port Blair Bases of the FSI to study the distribution, abundance and biology of tunas and associated species in the Indian waters (Fig. 1). Two vessels each were deployed for survey in the Arabian Sea and in the Bay of Bengal including Andaman & Nicobar waters. The fishing gear used and survey strategies adopted for collection of samples were as described previously[17]. While conventional Japanese multifilament longline with five hooks per basket was operated from the vessels *Yellow Fin* and *Blue Marlin*, the other two vessels operated monofilament longline gear with seven hooks per basket. There were major differences in the gear materials used and dimensions of different components of the two gears used in this study. The multifilament longline was made of tetron rope, whereas, the monofilament longline gear was made of nylon monofilament of lesser diameter and low specific gravity. The steel wires (*Sekiyama* and wire leader) on the branch lines were absent in monofilament gear used in this study. Lengths of various components also were different in these two types of longline gears used. The hooks used in multifilament longline in this study were Japanese tuna hooks (No. 3.6 SUN) whereas 16/0 tuna circle hooks were used in monofilament gear (Table 1). Every month, these vessels were deployed for voyages of 20 days duration, and about 15 longline sets were conducted in each voyage, operating an average of 8,500 hooks. Shooting of the longline gear starts before sunrise and is completed in about two to 2.5 hours. On an average 550 hooks are operated in a set. Immersion time of about 4 hours is allowed and hauling is done in the afternoon starting from the initially shot end (Table 2). Frozen Indian mackerel, nemipterids, sciaenids, round scads, sardines and occasionally squids were used as bait. The participating scientist collected the geo-referred data on the catch and oceanographic parameters of each fishing station. After the conclusion of each longline set, the species were identified by the scientist participant using taxonomic keys and online resources. Pelagic sharks recorded were identified following Compagno[18,19]. Morphometric measurements of individual sharks were taken at sea using measuring tape (±1 cm) and weighed (±1 kg) using a balance. Measurements such as total length (snout tip to tip of caudal fin) and pre-caudal length (snout tip to the upper caudal origin) and total weight were used for further analysis in our study. Sex was differentiated by observing the presence or absence of claspers.

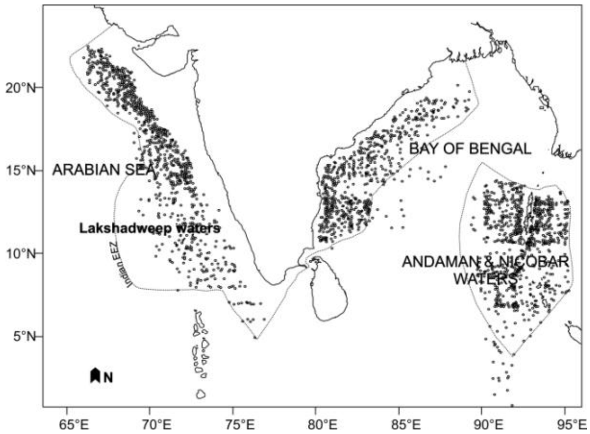

Fig. 1- Map showing the longline stations surveyed during the study

Table 1. Specifications of longline gears used for the survey

Gear components		Multifilament longline	Monofilament longline
Main line	Material	6.7 mm dia tetron rope	3.6 mm dia nylon
	Length	Continuous	Continuous
Float	Material	Polyethylene	Rigid plastic
	Diameter	300 mm	360 mm
Float line	Material	6.7 mm dia. Tetron rope	3.6 mm dia nylon
	Length	22m	20m
Branch line	Material	4.5 mm dia tetron rope	2.0 mm dia nylon
	Length	12 m	20 m
	Number	5	7
Sekiyama	Material	Steel wire (30x4x3)	Absent
	Length	6 m	
Leader wire	Material	Steel wire (30x4x3)	Absent
	Length	2 m	
Hooks		No. 3.6 sun Japanese tuna hooks	16/0 tuna circle hook

Corrections were incorporated on the field data verifying the validity of the taxonomic identification. Invalid taxa were replaced by valid synonyms and species which are unlikely to be captured using oceanic longlining (coastal species like *Scoliodon laticaudus* and *Carcharhinus macloti*) were degraded to higher taxonomic levels. Further, after confirming the identity of species by examining the field photographs, the species identified as *Carcharhinus melanopterus* were recorded as *Carcharhinus falciformis* (Dr. E.

Romanov, personal communication). For data analysis, the seas around India were divided in to three regions *viz*., eastern Arabian Sea, western Bay of Bengal and Andaman & Nicobar waters. The data collected during the study period were pooled separately for these three regions and nominal catch per unit effort (Hooking Rate (HR), the number of sharks caught in 100 hooks) was calculated. Diversity of pelagic sharks recorded from each area was quantified by calculating the Shannon-Wiener index (H')[20]. To study trends in the abundance indices of pelagic sharks, historic data on the bycatch of sharks in the tuna longline surveys conducted by six longliners of FSI in Indian waters during 1984-2010 were analysed by fitting linear regressions of log transformed hooking rate (ln(HR + 1)) values on year. Detailed analysis on the length frequency distribution, length weight relationship and sex ratio was carried out for five dominant species, *Alopias pelagicus, A. vulpinus, A. superciliosus, Carcharhinus limbatus* and *C. falciformis*. Measures are presented as means ± standard deviation.

Results

During the period 2004-2010, the seas around India were surveyed for oceanic tuna and allied resources by operating 1.2 million longline hooks. Total number of sharks caught in our study was 1501, registering a HR of 0.13 (±0.42). Sharks formed the second dominant group caught during the survey (Fig. 2) contributing 19.49% (by number) and 28.39% (by weight) to the total catch. Catches of sharks are prominent in Andaman & Nicobar region contributing 35.15% of the catch by number and 51.46% by weight. In the eastern Arabian Sea, sharks constituted 15.49% and 14.89% of the total catch by number and weight respectively, in the western Bay of Bengal, this group contributed 7.74% by number and 9.33% by weight to the total catch (Table 2).

Eighteen species of pelagic sharks were recorded in the tuna longline survey conducted in the Indian seas. Diversity of shark species was more in Andaman & Nicobar waters (16 species), followed by Arabian Sea (14 species) and from Bay of Bengal (11 species) (Table 3). However, due to dominance of thresher sharks in the catch Shannon-Wiener diversity index was low (1.52) for the Andaman & Nicobar waters compared to eastern Arabian Sea (1.73). Shannon-Wiener index estimated for pelagic shark diversity in western Bay of Bengal was 1.51.

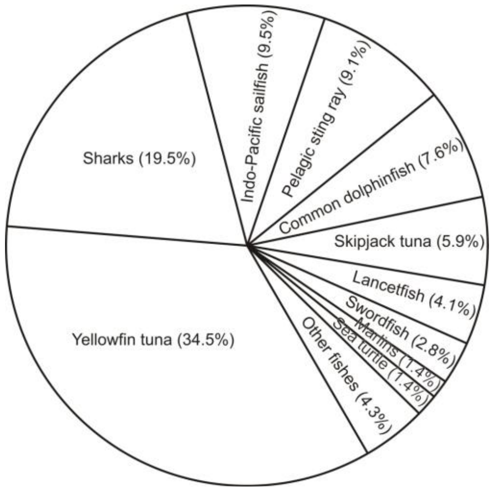

Fig. 2- Catch composition of tuna longline survey conducted in the Indian seas during the period 2004-2010

Species belonging to the family Alopiidae (thresher sharks) and family Carcharhinidae (requiem sharks) dominated the catch, contributing 82.94% by number and 84.54% by weight of the total shark catches. *Alopias pelagicus* predominated (HR – 0.039), contributing 31.25% to total catch by number and 37.46% by weight. *Carcharhinus limbatus*, *A. superciliosus*, *C. falciformis* and *A. vulpinus* were the other dominant species caught. Marked variations in the abundance of pelagic sharks were observed among the three regions studied. *A. pelagicus* remained the dominant shark species in the Andaman & Nicobar waters, while *C. limbatus* was dominated in the eastern Arabian Sea, whereas *C. falciformis* was dominant among the pelagic shark bycatch from the western Bay of Bengal. Dominance of thresher sharks (77.03% of the total numbers) in the bycatch from the Andaman & Nicobar region was clearly evident.

Geographical distribution of shark bycatch (Fig. 3) showed pelagic shark abundance in the Latitude/Longitude grids 5°N/93°E, 6°N/94°E, 7°N/93°E, 8°N/92°E, 9°N/92°E, 9°N/89°E and 11°N/92°E in the Andaman & Nicobar waters, 8°N/71°E, 9°N/75°E, 11°N/71°E and 19°N/69°E in the eastern Arabian Sea and 8°N/82°E and 20°N/84°E in the western Bay of Bengal. Temporally, higher shark catches were noticed during the months November, December and January. Seasonal variations in the pelagic shark abundance were pronounced in Arabian Sea and Andaman & Nicobar waters (Fig. 4). In the eastern Arabian Sea, the relative abundance (HR) of sharks ranged from0.02 (±0.14) in May to 0.39 (±0.76) in August with June to September period recording the higher catch of sharks. In the western Bay of Bengal, the HR varied between 0.01 (±0.04) in March to 0.17 (±0.80) in February. In the Andaman & Nicobar waters, the HR ranged from 0.09 (±0.20) in April to 0.42 (±0.60) in December with September – January season recording higher HR for sharks in this area.

Table 2- Year-wise details of survey conducted and hooking rates of sharks recorded in tuna longline survey in the Indian Seas

Year	Fishing effort (number of hooks)			Average number of hooks per set			Average soaking time (hrs)			Mean Shark HR (±S.D.)			% of sharks to total catch by number		
	AS	BoB	A&N	AS	BoB	A&N	AS	BoB	A&N	AS	BoB	A&N	AS	BoB	A&N
2004	15625	*	20949	531	*	622	5.05	*	4.48	0.03 (0.19)	*	0.41 (0.42)	13.79	*	38.64
2005	80695	38570	71349	478	455	559	4.01	4.03	4.13	0.13 (0.45)	0.12 (0.26)	0.32 (0.62)	14.27	11.29	33.78
2006	99035	75147	47800	501	566	576	3.97	3.97	4.47	0.11 (0.26)	0.09 (0.50)	0.21 (0.30)	19.45	16.42	30.96
2007	80258	69225	70781	585	589	570	4.17	4.23	3.12	0.15 (0.41)	0.04 (0.14)	0.27 (0.57)	15.18	4.22	32.82
2008	104950	82680	56820	531	616	558	4.49	4.68	4.18	0.07 (0.23)	0.03 (0.10)	0.19 (0.53)	14.74	4.83	37.54
2009	22286	52360	63095	454	616	575	4.39	4.74	3.98	0.07 (0.15)	0.01 (0.07)	0.13 (0.38)	9.8	4.35	39.34
2010	26342	54880	66330	486	575	566	4.03	4.38	4.19	0.07 (0.24)	0.01 (0.25)	0.12 (0.50)	18.45	4.12	41.62
All years	429191	372862	397124	514	566	574	4.22	4.26	4.02	0.10 (0.32)	0.05 (0.31)	0.22 (0.51)	15.49	7.74	35.15

*Survey was suspended in the Bay of Bengal during 2004

EAS – eastern Arabian Sea; WBoB – western Bay of Bengal; A&N – Andaman & Nicobar waters

Table 3- Pelagic sharks caught in the longline survey conducted in Indian Seas

Shark Species	Arabian Sea			Bay of Bengal			A & N Waters			All areas		
	HR	% by number	% by weight	HR	% by number	% by weight	HR	% by number	% by weight	HR	% by number	% by weight
Alopias pelagicus	0.007	6.29	11.31	0.007	14.36	24.36	0.105	47.43	44.59	0.039	31.25	37.46
A. superciliosus	0.001	0.67	1.43	0.001	1.66	2.35	0.037	16.91	20.46	0.013	10.26	15.76
A. vulpinus	0.001	0.45	0.48	0.001	2.21	3.68	0.028	12.69	13.04	0.010	7.79	10.18
Carcharhinus falciformis	0.013	12.58	10.37	0.022	45.86	31.91	0.002	0.69	0.82	0.012	9.66	5.26
C. limbatus	0.028	27.42	21.46	0.007	13.81	9.48	0.033	15.09	10.8	0.023	18.59	12.35
C. longimanus	0.001	0.45	0.14	<0.001	0.55	0.05	0.001	0.23	0.17	<0.001	0.33	0.15
C. albimarginatus	0.001	0.45	0.18	0.001	1.66	2.11	0.001	0.23	0.13	0.001	0.47	0.32
C. sorrah	0.005	5.17	5.87				0.001	0.46	0.31	0.002	1.8	1.15
C. obscurus							0.001	0.46	0.73	<0.001	0.27	0.54
C. dussumieri	0.004	3.6	3.66							0.001	1.07	0.57
Galeocerdo cuvieri	0.001	0.9	3.55	0.001	1.1	2.39	0.005	2.29	6.01	0.002	1.73	5.28
Isurus oxyrinchus	0.001	1.12	1.51	0.000	0.55	0.59	0.001	0.57	0.57	0.001	0.73	0.72
I. paucus	0.001	0.45	0.49							<0.001	0.13	0.08
Sphyrna lewini	0.001	1.12	2.97	0.003	6.63	11.8	<0.001	0.11	0.2	0.002	1.2	1.74
S. zygaena	0.001	0.45	2.77	0.000	0.55	0.35	0.001	0.34	0.6	0.001	0.4	0.92
S. mokarran							0.000	0.11	0.44	0.000	0.07	0.33
C. amblyrhynchos							0.002	0.69	0.47	0.001	0.4	0.35
Prionace glauca							0.001	0.23	0.2	<0.001	0.13	0.15
Carcharhinus spp.	0.004	3.82	2.87	0.002	3.31	1.87	0.002	0.91	0.47	0.003	2.07	0.98
Unidentified sharks	0.036	35.06	30.92	0.004	7.73	9.06	0.001	0.57	0*	0.015	11.66	5.71
TOTAL	0.104	100	100	0.049	100	100	0.220	100	100	0.125	100	100

* Shark escaped while hauling

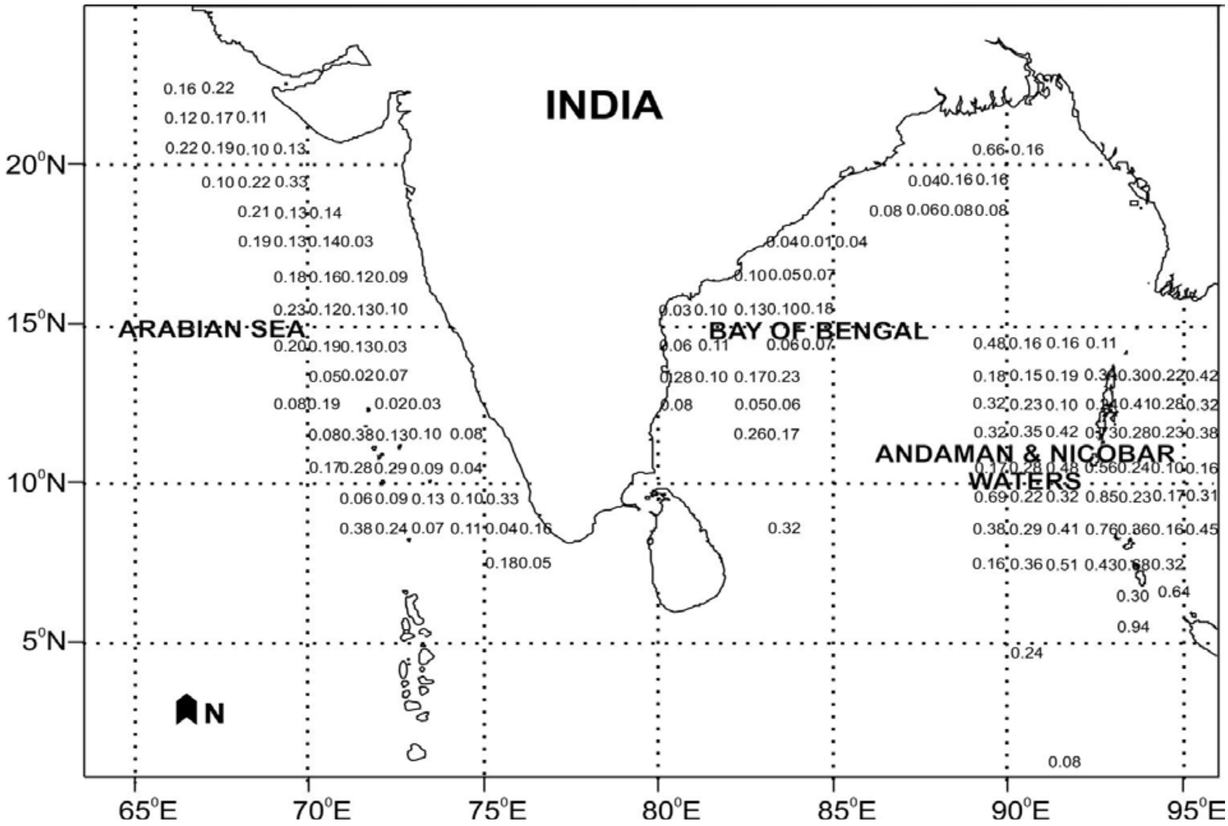

Fig. 3- Grid-wise (1° X 1°) average Hooking Rate (number in 100 hooks) of pelagic sharks bycatch in the tuna longline survey in Indian seas during 2004-2010

A comparative picture of shark bycatch by two different gears, monofilament and multifilament lines used in our study indicated that the shark bycatch was more in sets made using multifilament gear with wire leader, the total number recorded being 943 (35,278 kg) with a HR of 0.17 (Table 4). The monofilament gear recorded a lower catch of 558 specimens weighing 9783.70 kg with a HR of 0.09. The contribution of sharks by the multifilament gear was 30.57% by number and 45.97% by weight and by monofilament gear it was 12.09% by number and 11.93% by weight. Eighteen shark species were caught on multifilament gear, whereas, 14 species were caught on monofilament longline. However, Kruskal-Wallis test (H = 0.47, P = 0.49) did not reveal any significant difference in the hooking rates of pelagic shark species caught by these two gears.

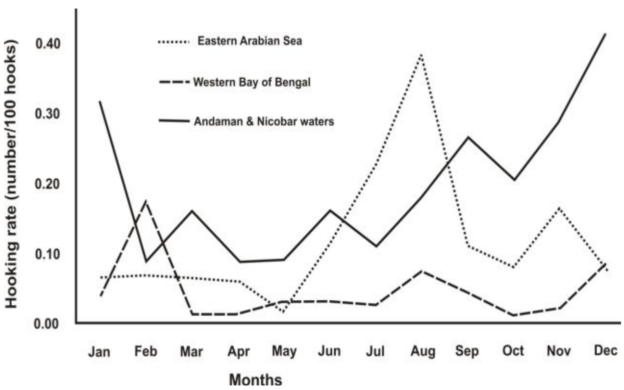

Fig. 4- Monthly Hooking Rate (number caught in 100 hooks operated) of pelagic sharks caught during longline survey conducted in three regions of Indian Seas

The relative abundance indices of sharks in the eastern Arabian Sea revealed a gradual declining trend in the catch over the years (Fig. 5). The HR recorded during 1980's and early 1990's were impressive, and thereafter there was drastic reduction in the relative abundance indices (linear regression; slope: -0.054; R^2: 0.67). In the western Bay of Bengal, drastic fall in shark abundance was noticed over the years in our analysis (linear regression; slope: -0.052; R^2: 0.65). High HR of 8.14% was recorded during 1985, while in recent years (2005–2010) very low hooking rate was recorded (0.01–0.12). In the Andaman & Nicobar waters, there was no clear indication of reduction in abundance over the years, as the relative abundance indices fluctuated over the years (linear regression; slope: -0.023; R^2: 0.29).

Table 4- Pelagic sharks recorded as bycatch in the monofilament and multifilament longline survey conducted the Indian EEZ

Shark Species	Monofilament			Multifilament		
	HR	% by number	% by weight	HR	% by number	% by weight
Alopias pelagicus	0.0062	6.99	14.73	0.0755	45.60	44.59
Alopias superciliosus	0.0010	1.08	2.05	0.0260	15.69	20.46
Alopias vulpinus	0.0008	0.90	1.71	0.0197	11.88	13.04
Carcharhinus falciformis	0.0221	24.91	21.40	0.0011	0.64	0.82
Carcharhinus limbatus	0.0224	25.27	17.95	0.0242	14.63	10.80
Carcharhinus longimanus	0.0005	0.54	0.12	0.0004	0.21	0.17
Carcharhinus albimarginatus	0.0005	0.54	0.92	0.0007	0.42	0.13
Carcharhinus sorrah	0.0033	3.76	4.11	0.0011	0.64	0.31
Carcharhinus obscurus				0.0007	0.42	0.73
Carcharhinus dussumieri	0.0019	2.15	2.03	0.0007	0.42	0.00
Galeocerdo cuvieri	0.0006	0.72	1.82	0.0039	2.33	6.01
Isurus oxyrinchus	0.0002	0.18	0.26	0.0018	1.06	0.57
Isurus paucus	0.0003	0.36	0.36	0.0000	0.00	0.00
Sphyrna lewini	0.0027	3.05	7.29	0.0002	0.11	0.20
Sphyrna zygaena	0.0005	0.54	2.16	0.0005	0.32	0.60
Sphyrna mokarran				0.0002	0.11	0.44
Carcharhinus amblyrhynchos				0.0011	0.64	0.47
Prionace glauca				0.0004	0.21	0.20
Carcharhinus spp.	0.0022	2.51	1.73	0.0030	1.80	0.47
Unidentified sharks	0.0235	26.52	21.36	0.0047	2.86	0.00
TOTAL	0.0886			0.1656		

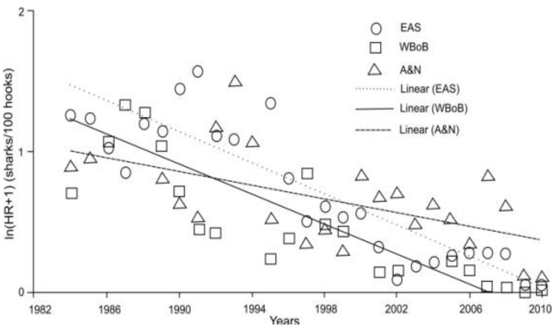

Fig. 5- Trends in the relative abundance (HR, number in 100 hooks) of pelagic sharks caught in tuna longline survey in the Indian seas (EAS – eastern Arabian Sea; WBoB – western Bay of Bengal; A&N – Andaman & Nicobar waters)

Detailed information on the length, weight and sex were collected from 389 specimens of five selected shark species (table 5, fig. 6). Among the five, highest average total length, precaudal length and weight were recorded for the species *A. superciliosus* whereas, lowest values for these measures were recoded for *C. falciformis*. Chi-square tests on sex ratio revealed the significant predominance of males in the population of three species of Genus *Alopias*. Whereas male to female ratios were near to unity in the case of requiem sharks (*C. limbatus* and *C. falciformis*). Length-weight relationship indicated isometric growth in *C. limbatus* and A. *superciliosus*, whereas, growth was allometric in the remaining species (table 5).

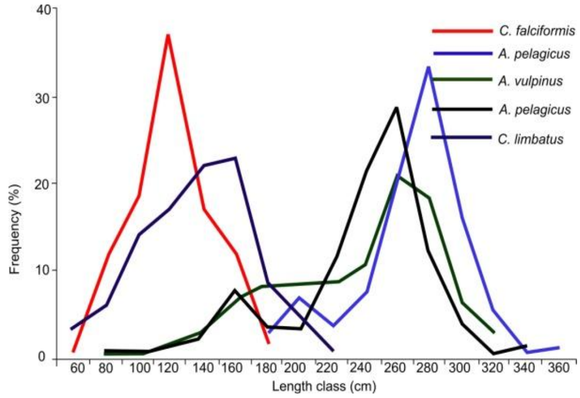

Fig. 6- Length frequency of five major species of pelagic sharks in Indian tuna longline fishery

Table 5- Sex ratio, length and weight parameters of the major species studied

Species	*A. pelagicus*	*A. vulpinus*	*A. superciliosus*	*C. falciformis*	*C. limbatus*
Number of observations	162	52	43	45	87
Sex ratio (M:F)	1.75:1	4.2:1	2.6:1	0.9:1	1.23:1
Total Length in cm (Av± SD)	245.04 ± 47.05	242.93 ± 49.76	276.05 ± 34.87	131.96 ± 26.57	148.44 ± 34.16
Precaudal length in cm (Av± SD)	128.76 ± 24.94	129.09 ± 19.18	152.19 ± 21.48	104.61 ± 20.75	116.05 ± 26.88
Weight in kg (Av± SD)	36.71 ± 16.48	35.53 ± 28.93	60.51 ± 23.85	13.76 ± 8.67	21.12 ± 14.55
Equation for total length-weight relationship and (r)	$W = 0.000012TL^{2.70}$ (0.92)	$W = 0.000014TL^{2.67}$ (0.84)	$W = 0.000003TL^{2.98}$ (0.87)	$W = 0.00002TL^{2.73}$ (0.94)	$W = 0.000006TL^{3.00}$ (0.94)
Equation for precaudal length-weight relationship and (r)	$W = 0.00004PCL^{2.78}$ (0.91)	$W = 0.000091PCL^{2.63}$ (0.87)	$W = 0.00012PCL^{2.60}$ (0.86)	$W = 0.00002PCL^{2.81}$ (0.91)	$W = 0.00001PCL^{2.96}$ (0.92)

Discussion

Fourteen species of pelagic sharks were reported by John and Neelakandan[13] from the bycatch of tuna longline survey conducted in the Bay of Bengal while Bhargava *et al*.[12] listed 15 species of pelagic sharks in the tuna longline survey in the Indian seas. The present study documented 18 shark species in the longline operations in the Indian seas. However, Romanov *et al*.[21] documented 29 pelagic shark species in longline operations conducted in the Indian Ocean during 1961-2010. Studies conducted in the Venezuelan waters recorded 25 pelagic shark species in longline fishery[22]. *A. pelagicus* was the most abundant shark species in our study. *Prionace glauca*, the most abundant pelagic shark species in the longline operations conducted in other parts of world oceans[8-9,22-23] was not present in significant numbers in the Indian seas.

The index of relative abundance (HR) of sharks in the present study is considerably lower than the index reported in earlier studies[6,10,12,13,24-25] indicating a decline in the abundance over the years. John and Varghese[15] and Romanov *et al*.[21] also have documented drastic decline in the pelagic shark abundance indices in different regions of Indian Ocean including Indian waters. Our study reveals that, this decline in pelagic shark abundance was more pronounced in the eastern Arabian Sea as well as western Bay of Bengal, whereas, the decline was not significant in the Andaman & Nicobar waters, establishing the importance of this region as the potential area for conservation of these ecologically and economically important group. This trend may be partially attributed to comparatively less intense longline fishing activities in the Andaman & Nicobar waters in the past (Dr. M. E. John, personal communication). However, in recent years, Andaman & Nicobar waters also is experiencing increasing activity of longliners, since the tuna fishing vessels in the western Indian Ocean are now shifting their fishing eastward due to piracy threats[26].

Most of shark species recorded in our study figure in the IUCN Red List of Threatened Species[28]. Out of 18 species of sharks documented, eight species each are ‘vulnerable’ and ‘near threatened’ while two species are categorized as ‘endangered’ (Table 6). The crucial role of sharks as a top predator and scavenger of the ocean emphasize the need for protection of sharks to maintain ecological balance of the oceans[27]. Changes in shark populations are likely to have profound effects throughout the marine food web[8,27]. Therefore, the decline of shark population may have serious ecological implications. Another aspect of pelagic shark bycatch is that, in most of the cases, the industry discards the carcass of sharks in the sea after removing the fins (finning). Finning is contrary to the Article 7.2.2 (g) of the FAO Code of Conduct for Responsible Fisheries (CCRF) which stresses the importance of avoiding waste and discards in any fishery. Further, finning denies the opportunity for collection of critical data required to undertake rigorous assessment of stock status of shark species and the impact of fisheries on sharks. Since the shark flesh is having good market in India, gillnet and small scale longline units land sharks with fins attached and the finning is done at the landing centers or processing plants (Fig. 7-8).

In the present study, higher catch rates for sharks were recorded in multifilament gear with wire leaders than monofilament longline gear. This difference could be due to the absence of wire leader in the monofilament longline gear used in this study. Sharks caught in the monofilament longline may be able to escape by biting off the nylon monofilament line while it may be difficult to bite and break the steel leader wire in the multifilament longline gear used in our study. Ward *et al*.[29] had reported lower catch rate of sharks in the longline using nylon than wire leaders in studies conducted off northeastern Australia. Another major difference in the longline gears used in our study was types of hooks. Monofilament longline gear in our study used circular hook (16/0 tuna circle hook) while Japanese tuna hooks (No. 3.6 SUN) were used in our multifilament longline gears. However, studies conducted in other parts of the world oceans revealed that the circle hooks had little impact on catch rate of sharks than the conventional J hooks[30-31]. Circle hooks in longline fishery can help to reduce hooking in the gut and gill and increase hooking on jaws so that fish can easily escape or get released[29,32].

Table 6- IUCN status of pelagic sharks caught in longline survey conducted in Indian Seas

Shark Species	**IUCN status**
Alopias pelagicus	Vulnerable
Alopias superciliosus	Vulnerable
Alopias vulpinus	Vulnerable
Carcharhinus albimarginatus	Near threatened
Carcharhinus amblyrhynchos	Near threatened
Carcharhinus dussumieri	Near threatened
Carcharhinus falciformis	Near Threatened
Carcharhinus limbatus	Near threatened
Carcharhinus longimanus	Vulnerable
Carcharhinus obscurus	Vulnerable
Carcharhinus sorrah	Near Threatened
Galeocerdo cuvier	Near threatened
Isurus oxyrinchus	Vulnerable
Isurus paucus	Vulnerable
Prionace glauca	Near Threatened
Sphyrna lewini	Endangered
Sphyrna mokarran	Endangered
Sphyrna zygaena	Vulnerable

Fig. 7- Pelagic sharks landed by small scale longliners at the Cochin Fisheries harbor

Fig. 8- Finning of sharks landed by small scale longliners at the Cochin Fisheries harbor

Reducing shark capture through the use of time and area closures is a good option available to fishery managers. Use of shark repellents, including ammonium acetate and other semiochemicals emitted from predators and use of magnet or electropositive metal near hook also have proved to be effective in reducing shark bycatch in longline fishery[33-37]. Use of such chemicals and metallic repellents may further help reducing the extent of depredation (i.e., damage caused to gear, bait, and targeted fish species) by sharks in longlining. Varghese *et al*.[38] attributed sharks as the main predator responsible for the damage to longline caught tunas and billfishes to the extent of 8490 t annually by depredation in Indian waters (Fig. 9).

Scientists have documented growing concern over the widespread decline of shark populations all over the world[27,39-42]. Population dynamics of most of the sharks is similar to whales, characterized by slow growth, late maturity and low fecundity and therefore, they can withstand only modest level of fishing without depletion and stock collapse[43]. The effect of fishing on shark stocks has become the focus in many international fora, resulting in the development of International Plan of Action to conserve and manage sharks (IPOA-SHARKS). IPOA-SHARKS aims at ensuring the conservation and management of sharks and their long-term sustainability, owing to the vulnerability of sharks and to keep the total fishing mortality for each stock within sustainable limits[44]. FAO had requested all the fishing nations to prepare National Plan of Actions to conserve and manage sharks (NPOA-SHARKS) by 2001[45].

Scientists and fishery managers need to pay attentions to the present status of pelagic sharks occurring in Indian seas to evolve and adopt suitable management measures for ensuring sustainability. Most of the nations in this region are yet to formulate NPOA-SHARKS[46], although national consultation and also regional consultations, jointly by Bangladesh, India, Maldives and Sri Lanka are in progress[47].

Fig. 9- Depredation by shark on the yellowfin tuna caught during tuna longline survey in the eastern Arabian Sea

Measures, such as replacing steel wire tracers with nylon monofilament tracers; encouraging use of circle hooks; ensuring observer coverage in industrial longline fishery; encouraging the safe release of sharks taken as bycatch in live condition are useful steps for shark conservation. Enforcing ban on wasteful practice of shark finning thereby promote full utilization of shark meat as protein food and to facilitate collection of biological data at species level must be adopted on emergency basis for ensuring the sustainable management of pelagic sharks. Enforcing time and area closure for high sea fisheries and fleet reduction by the major distant water fishing nations engaged in tuna fishery in these areas should also be adopted in consultation with Regional Fisheries Management Organisation like Indian Ocean Tuna Commission (IOTC).

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