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Fishery of elasmobranchs with some observations on the biology and stock assessment of *Carcharhinus limbatus* (P. Muller & Henle, 1839) exploited along Malabar coast

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ABSTRACT

Elasmobranchs are caught in trawls, gillnets and longlines along the Malabar region of Kerala and they are landed almost round the year, accounting less than 1% of the total catch. The catch of elasmobranchs during the period 2001-2011 has shown a declining trend, but towards the end of this period the fishery has improved marginally. The contribution of trawl, gillnets, longlines and other gears were 43.1%, 31.3%, 21.1%, and 4.5 % respectively. The contribution of sharks, rays and skates were 70.8%, 24.2% and 5.0% respectively. Twenty four species of sharks, 8 species of rays and 2 species of skates were recorded in the catch. Length-weight relationship was estimated for *Carcharhinus limbatus* and the regression equation for both the sexes was $W = 0.00001486L^{2.80214}$ (r=0.9661). The overall F: M ratio was estimated as 1:1.59; females predominated the catches in almost all months. The growth of this species is described by the equation $L_t = 302 (1-e^{-(0.45)[t-(-1.2)]})$. The species grows fast during the early stages of its life. The annual average exploitation ratio (E) is estimated as 0.74 which is higher than the optimum exploitation rate estimated. The present study showed that *C. limbatus* is heavily targeted, hence this species is at risk of being overexploited and is in need of immediate management.

Keywords: Elasmobranchs, Fishery, Malabar, Mortality, Stock assessment

Introduction

Elasmobranchs are an important demersal resource exploited along the Malabar coast. They are caught throughout the year by trawl, gillnet and longlines. Among the elasmobranchs, sharks form the dominant resource followed by rays and skates. There is very good demand for this resource in fresh and dried condition. Information on the elasmobranchs of Malabar region is scanty except for works by Devadoss (1984, 1998), Devadoss *et al.* (2000) and Raje *et al.* (2002, 2007). Based on exploratory surveys, Sudarsan *et al.* (1989) and Ninan *et al*. (1992) gave quantitative assessment of elasmobranchs along the outer continental shelf and slope of the south-west coast. In the present study, an attempt has been made to put together detailed information on the fishery of elasmobranchs along this coast, with some information on the biology and stock assessment of *Carcharhinus limbatus*.

Materials and methods

The data on the landing of elasmobranchs along the Malabar region by trawls, gillnets, longlines and other gears for the period 2001-2011 collected by the Central Mrine Fisheries Research Institute (CMFRI) from Malappuram, Kozhikode, Kannur and Kasaragod districts of Kerala were used for this study. The length frequency data of *C. limbatus* collected from the landing centers at weekly intervals during 2005-2011 were used for estimation of growth and population parameters. A total of 2088 specimens in the length (total length, TL) range of 62-238.2 cm were used for the study. The data on length was grouped into 5 cm class intervals and the raised monthly frequency distribution was used for the growth studies following Sekharan (1962). Length-weight relationship was studied following Le Cren (1951). A total of 1,151 males in the range of 65.1-211.2 cm (2.6 - 76.8 kg weight) and 1,100 females in the range of 75.8-238.2 cm (2.3-82.5 kg weight) were used for determining the length-weight relationship of *C. limbatus*. The relationship was estimated by the least square method. Growth and mortality parameters were estimated using FiSAT programme (Gayanilo Jr. *et al*., 1996) after pooling the annual data for the period 2005-2011. Natural mortality (M) was estimated from the empirical formula as in Pauly (1980), by taking the mean seawater temperature as 28°C and the total mortality (Z) from the catch curve as in Pauly (1983). The exploitation ratio (E) was estimated by the ratio of fishing mortality to total mortality. The exploitation rate 'U' was estimated by the formula $U = F/Z^* (1-e^{-Z})$. The average exploitation rate over the period of study was estimated by pooling data for the period 2005-2011. The

length at first recruitment was taken as the smallest length in the length frequency distribution and the length at first capture was obtained as the mid length of the first peak in length frequency distribution. The spawning stock biomass and standing stock biomass was assessed using the Beverton and Holt model (Beverton and Holt, 1957).

Results

Fishery

The total catch of elasmobranchs by all gears along the Malabar coast fluctuated between 279 t in 2010 and 1828 t in 2003 with an annual average of 775 t (0.4%). The contribution of trawls, gillnets, longlines and other gears were 43.1%, 31.3%, 21.1%, and 4.5% respectively. The catch showed a declining trend initially, but towards the end of the period the fishery improved marginally (Fig. 1). The contribution of sharks, rays and skates were 70.8%, 24.2% and 5.0% respectively (Fig. 2). Peak landings were noticed in January-May, when more than 60% of the elasmobranchs were landed (Fig. 3).

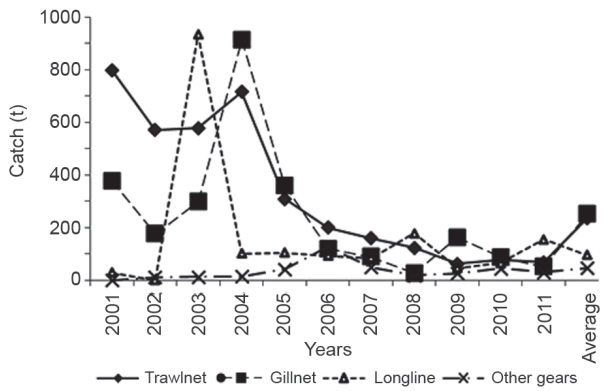

Fig. 1. Gearwise catch of elasmobranchs along Malabar coast

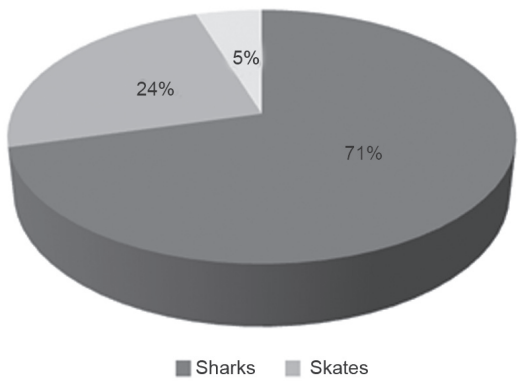

Fig. 2. Percentage composition of elasmobranchs during 2001-2011

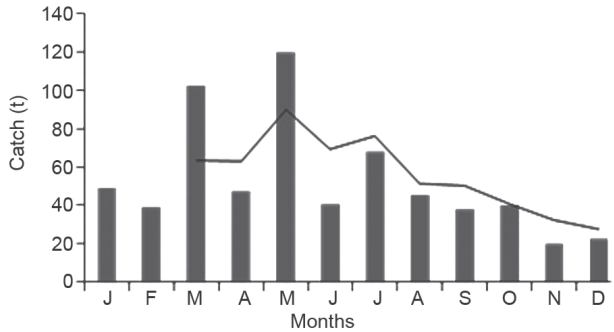

Fig. 3. Monthwise average contribution of elasmobranchs during 2001-2011

Trawl fishery

Elasmobranchs were incidentally caught by commercial trawlers of OAL 32-68' operating in 15-140 m depth range at a distance of 6-50 km from the shore depending upon the season and availability of fish. More than 70% of the trawlers carry out multiday fishing for 5-6 days and the rest, single day fishing. The cod end mesh size of trawl net ranged between 15 and 18 mm. Trawl fishery in Malabar region is based at Ponnani, Beypore, Puthiappa, Chombala and Azheekal. Elasmobranchs in trawls formed less than 1% of the catch. Yearwise landing has shown a decreasing trend from 799 t in 2001 to 63 t in 2009, and the average for this period was 333 t. The catch rate of elasmobranchs in trawl was less than 1 kg h^{-1} (Fig. 4).

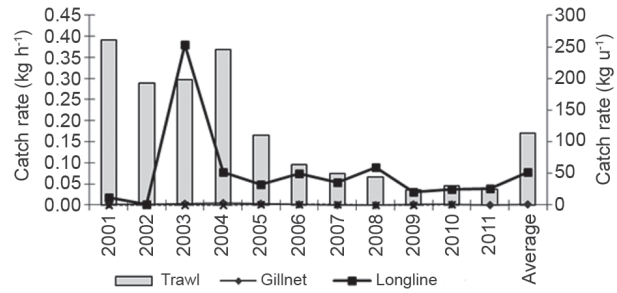

Fig. 4. Gearwise catch rate of elasmobranchs during 2001-2011

Gillnet fishery

Gillnet fishery was observed throughout the year at Ponnani, Beypore, Chaliyam, Puthiappa, Vellayil, Elathur, Chombala, Quilandy and Azheekal. Elasmobranchs were observed in landings by gillnets operated from mechanised, motorised and non-mechanised crafts. Most of the gillnets were of 80-180 mm mesh. Surface set gillnets were used to target large sharks while the bottom set nets targeted small sharks and rays. The length of gillnets was highly variable and ranged from 1200 to 1800 m. In the Malabar region, the annual elasmobranch landings varied between 27 t

(2008) and 915 t (2004), and the average catch for this period was 243 t. The elasmobranch landing showed a declining trend from 2005 onwards although the effort was around 2 million units. This decline may be due to high fishing pressure on coastal sharks. The annual catch rates of elasmobranchs in gillnet was around 1 kg unit^{-1}**.** Bottom set and surface set gillnets were the primary gear employed in gillnet fishery. Soak time ranged between 8 and 12 h. Sharks, skates and rays contributed 76.3%, 0.80 % and 22.9 % respectively. The annual effort of gillnets also showed a reduction from 0.28 to 0.17 million fishing units and the annual average effort for the study period was 0.21 million fishing units. The catch rate also declined from 1.69 kg unit^{-1} in 2005 to 0.67 kg unit^{-1} in 2006. A reduction in the annual effort in gillnet was noticed during 2006 (Fig. 5).

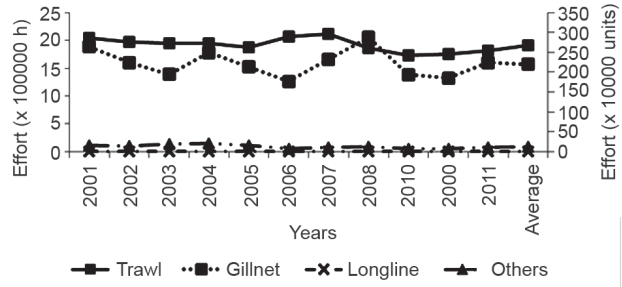

Fig. 5. Annual effort expended by different gears along the Malabar coast

Table. 1. Gearwise species composition (%) of sharks and rays in Malabar region during 2001-2011

Species	Trawl	Gillnet	Longline	Others	Average
Sharks					
Alopias vulpinus	0.41	1.34	3.15	6.55	2.86
Carcharhinus dussumieri	4.05	-	4.92	-	2.24
C. falciformis	0.15	-	0.74	-	0.22
C. limbatus	27.48	40.73	51.44	50.64	42.57
C. longimanus	-	-	0.37	-	0.09
C. macloti	-	-	0.18	-	0.05
C. melanopterus	27.46	16.80	9.03	18.72	18.00
C. obcsurus	-	-	0.54	-	0.14
C. sorrah	15.45	8.19	8.93	1.73	8.58
C. amblyrhynhoides	-	-	1.04	-	0.26
C. brevipinna	0.15	-	0.31	-	0.12
C. leucas	-	-	0.52	3.15	0.92
Chiloscyllium indicum	2.25	-	0.12	-	0.59
Echinorhinus brucus	-	-	-	0.24	0.06
Galeocerdo cuvier	0.28	-	0.74	1.69	0.68
G. obscurus	-	0.89	-	-	0.22
Hemipristis elongatus	0.15	-	-	-	0.04
Isurus oxyrinchus	-	-	0.92	-	0.23
Rhizoprionodon acutus	-	-	1.19	-	0.30
R. oligolinx	-	-	0.25	-	0.06
Scoliodon laticaudus	6.36	1.98	-	-	2.08
Sphyrna lewini	0.81	7.50	0.88	2.34	2.88
S. zygaena	15.02	22.58	14.46	14.94	16.75
Triaenodon obesus	-	-	0.27	-	0.07
Rays					
Species	Trawl	Gillnet	Longline	Others	Average
Gymnura macrura	15.00	9.24	-	-	6.06
G. poecilura	3.45	3.51	-	-	1.74
Dasyatis uarnak	4.68	17.33	29.85	21.66	18.38
D. bleekeri	8.05	13.73	11.98	11.56	11.33
D. sephen	5.02	3.78	7.97	8.34	6.28
Aetobatus narinari	57.92	51.92	22.96	30.52	40.83
Mobula sp.	5.88	0.17	27.24	27.26	15.14
Rhinoptera javanica	-	0.32	-	0.68	0.25

Longline fishery

Longline fishery is mainly based at Azheekal in Kannur and Elathur and Chaliyam in Calicut. Introduction of multiday fishing by longliners by the migrating fishermen from Thuthur between Kanaykumari and Ratnagiri based at Azheekal enabled extension of fishing grounds along the entire south-west coast. The fishery commences in November and extends up to May. About 400-800 hooks of size number 2 are employed from each boat at a depth range of 100-200 m, and the units remain in the sea for nearly 5-15 days. The average longline contribution was 163 t (19.3 %) and it ranged between 1 t (2002) and 934 t (2003). The catch rate showed a decreasing trend from 252 kg unit^{-1} in 2003 to 20.3 kg unit^{-1} in 2008. Highest catch rate was recorded in March and lowest in July and the average catch rate observed was 38.8 kg unit^{-1}. The average contribution of sharks and rays in this gear was 97.3% and 2.7% respectively.

Species composition

Species composition of elasmobranchs landed during 2001-11 is given in Table 1. In all, 24 species of sharks, 8 species of rays and 2 species of skates were recorded in the catch *C. limbatus* (42.6%) was the dominant species among sharks, followed by *Carcharhinus melanopterus* (18.0%), *Sphyrna zygaena* (16.7%), *Carcharhinus sorrah* (8.6%), *Sphyrna lewini* (2.9%), *Carcharhinus. dussumieri* (2.2%) and *Scoliodon laticaudus* (2.1%). Gearwise contribution of different species showed that *C. limbatus*, *C. melanopterus*, *S. zygaena* were the most commonly seen species in all the gears. Besides the common species usually found in the catches, other species of sharks have also emerged in the longline and trawl fishery. *Alopias vulpinus, Carcharhinus longimanus, Carcharhinus. obscurus, Carcharhinus leucas, Echinorhinus brucus, Isurus oxyrinchus* and *Triaenodon obesus* started to appear in the fishery from 2005 onwards. In the beginning, these species especially, *A. vulpinus*, were caught occasionally. Now they are seen regularly in longline catches from September to May. Increase in the depth and area of fishing operations has resulted in a change in species composition of sharks.

Eight species of rays belonging to 5 genera were observed in the fishery. *Aetobatus narinari* (40.8%) was the most common species found in the catch, followed by *Dasyatis uarnak* (18.3%), *Mobula* spp, (15.1%), *Gymnura micrura* (12.1%), *Dasyatis sephen* (6.2%), *Gymnura poecilura* (3.48%) and *Rhinoptera javanica* (0.5%). *Rhynchobatus djiddensis* and *Rhina ancylostoma* were the only two species of skates found in the fishery. They were occasionally found in the trawl landings.

Biology of C. limbatus

Size distribution

The catch of *C. limbatus* in trawl was supported by individuals in the size range of 60-152.1 cm with 90.2 cm as mean size. The major share, accounting for 62.5% of the catch in number, was supported by individuals in the size range of 91-120 cm. The size of *C. limbatus* caught in gillnet was relatively bigger, 62.1-162.8 cm, compared to those caught by trawl net, and the major share of the gllnet catch was dominated by individuals in the size range of 120-140 cm. The size of *C. limbatus* caught in longlines was much larger, being in the range of 94.8 to 238.2 cm with mean size of 135 cm compared to those caught in gillnet and trawl net. This fishery was sustained mainly by individuals in the size range of 120 - 180 cm, representing 75% of the catch. Yearwise fluctuation in the mean size in all these gears has shown that the mean size has declined. Observations for the seven-year period show that there was a marginal decline in the size of *C. limbatus* occurring in the trawl and longline fisheries (Fig. 6).

Length -weight relationship

The length-weight equations for both the sexes were derived as:

Female: $W = 0.00001472\ L^{2.8514}$ (r=0.9512)

Male: $W = 0.000015005\ L^{2.8215}$ (r=0.9665)

Analysis of covariance showed that there was no significant difference at 5% level between sexes and the common equation was:

$W = 0.00001486L^{2.80214}$ (r=0.9661)

Sex ratio

The females of *C. limbatus* grow larger and live longer than the males. The largest female measured during this study period was 238.8 cm and the male 211.2 cm. Month-wise distribution of sex ratio of 2088 specimens of *C. limbatus* (average of seven years) is given in Fig. 7. The overall male-female ratio being 1: 1.59, females dominated males in almost all months. Chi-square test indicated that the differences noticed in the ratio were not significant at 5% level.

Growth parameters

Growth parameters estimated for *C. limbatus* by studying the modal progression of cohorts over time were $L_\infty = 302$ cm and K = 0.45 The growth of this species is described by the equation $L_t = 302\ (1\text{-}e^{-(0.45)\ [t-(-1.2)]})$. This shows that the species grows fast during the early stages of its life. They attain 64.92, 89.6, 111.7, 131.5, 149.3, 165.2, 179.4, 192.2, 203.6 and 214.6 cm at the end of 1st to 10th years. The minimum age of the fish in the catch was 1 year,

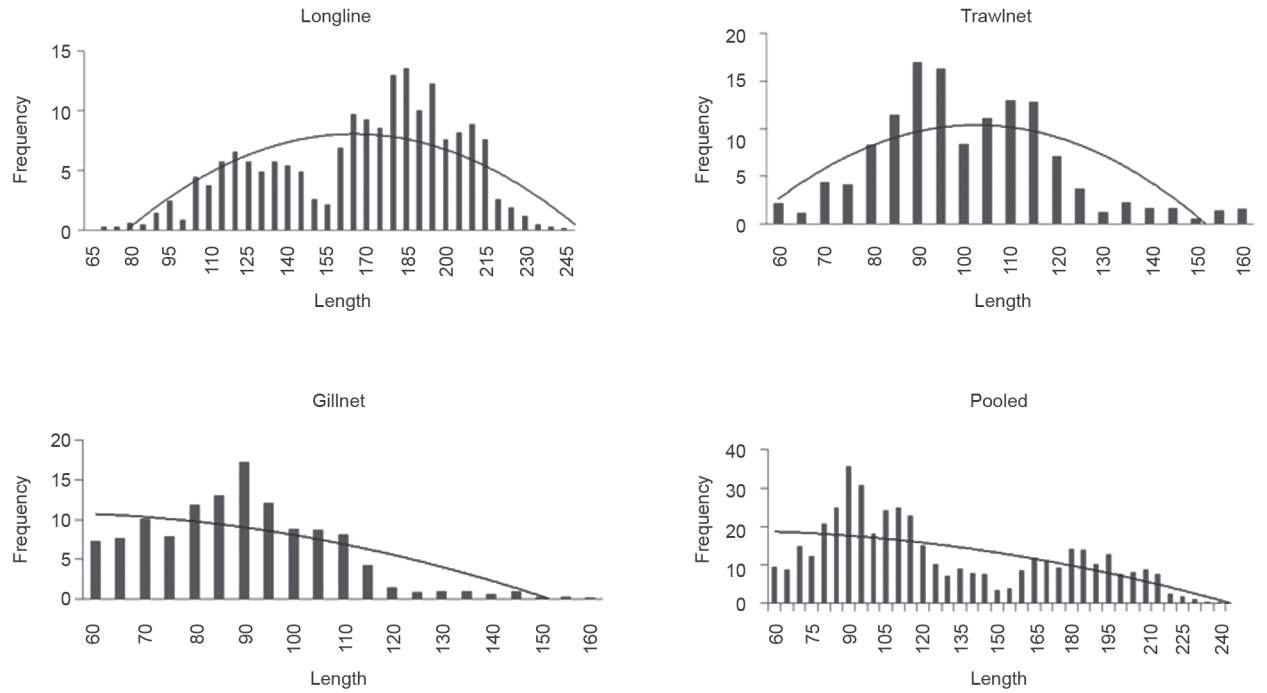

Fig. 6. Length frequency distribution of *C. limbatus* in different gears during 2005-2011

with 3-5 years as the dominant age group constituting the fishery.

Mortality parameters

The estimated Z ranged between 1.89 y^{-1} (2006) and 2.73 y^{-1} (2005). The natural mortality (M) was 0.54 y^{-1}. Fishing mortality (F) ranged between 2.19 y^{-1} (2005) and 1.35 y^{-1} (2006) and the average for this period was 1.68 y^{-1} (Table.2).

Status of the stock

The length at first capture (Lc) and length at recruitment (Lr) of *C. limbatus* were estimated as 94.5 cm and 60.2 cm respectively. Relative yield per recruit (Y/R) was maximum for an exploitation ratio (E) of 0.80 (2005) and minimum of 0.69 (2009). The average exploitation ratio

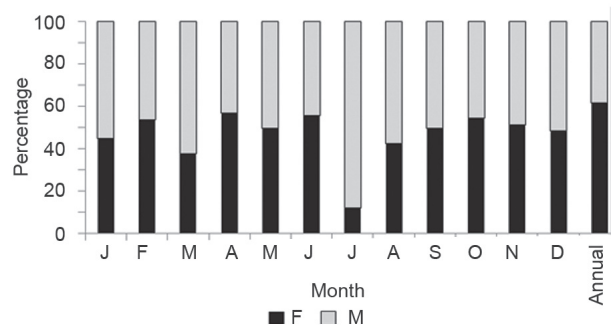

Fig. 7. Sex ratio of *C. limbatus* during 2005-2011

(E) was estimated as 0.74, which is higher than the optimum exploitation rate estimated by the Beverton and Holt method. The spawning stock biomass (SSB) varied from 31 t (2009) to 402 t (2005) and the average SSB for this

Table.2. Estimates of total mortality (Z), fishing mortality (F), natural mortality (M), Exploitaion rate (U), Exploitation ratio (E) SSB, St.SB and yield of *C. limbatus*

Year	Z	F	M	U	E	SSB (t)	St.SB (t)	Yield (t)
2005	2.73	2.19	0.54	0.74	0.80	189	402	418
2006	1.89	1.35	0.54	0.66	0.71	142	285	221
2007	2.05	1.51	0.54	0.64	0.74	64	138	135
2008	2.18	1.64	0.54	0.66	0.75	97	168	100
2009	2.24	1.70	0.54	0.67	0.69	31	61	74
2010	2.12	1.58	0.54	0.65	0.75	70	70	71
2011	2.26	1.77	0.54	0.71	0.78	34	65	63
Average	2.21	1.68	0.54	0.68	0.75	90	170	156

period was 90 t. The standing stock biomass (StSB) estimated ranged from 61 t (2009) to 402 t (2005) and the average for this period was 170 t.

Discussion

Elasmobranch fishery along the Malabar coast expanded rapidly as bycatch of accelerated multiday trawling, gillnetting and longlining. At the same time, demand for elasmobranch meat (in fresh or processed form) and byproducts steadily increased.While the annual elasmobranch landings decreased over the period between 2001 and 2011, the teleost landings also decreased, suggesting that there has not been an obvious shift in target taxa (Manojkumar and Pavithran, 2011). Between 1992 and 1999 the fishing fleet decreased by 23.1% and total landings declined for all species of fishes and invertebrates. During this period elasmobranch landings decreased by 32.7% suggesting that a reduction in the size of the fishing fleet alone did not account for the decline in elasmobranch landings (Devadoss *et al*., 2000). The increase in landings between 2001 and 2004 could have been the result of increasing demand. One possible scenario is that an interest in marketing elasmobranchs was rekindled when deep-sea sharks were caught in large numbers in longline and gillnet fishery. When the value of the meat was recognised and demand grew, elasmobranchs may have been increasingly targeted during the late 1980's and early 1990's. Traditional longline fishers of Malabar in north Kerala are also known to conduct shark fishing in certain locations like Elathoor (Vivekanandan, 2001).

Some of the elasmobranch species landed during the period of study were of rare occurrence. These included *Torpedo* spp., *I. oxyrinchus*, and *E. brucus*. *A. vulpinus* demonstrated increased landings and a significantly increased price over the period of study. As these species may be subjected to commercial exploitation, their stocks should be monitored closely, allowing the formulation of adequate management strategies. Changes in the species composition of elasmobranchs as a result of extension of fishing ground are noteworthy.

Seasonal abundance in the present study shows a similar pattern as observed by Ninan *et al.* (1992) along the south-west coast, including the Wadge Bank, with high catch rate during September-March. Devadoss (1977), Devadoss *et al.* (1989) and Grace Mathew (1996) also noticed a similar pattern of seasonal abundance and has correlated this with the availability of pelagic fish stock like sardines, mackerels *etc*. during this period. Along the Malabar coast, there is more concentration of elasmobranchs, especially of sharks in the shallower strata during April-October. Results showed that *C. limbatus* was the most abundant shark species caught both in the Malabar and adjacent areas. Increased demand for shark fins and meat encouraged the fishermen to expand the fishing operations and catch sharks of families other than Carcharhinidae, with larger fins and better meat quality.

The 'K' value estimated in *C. limbatus* is very low. According to Beverton and Holt (1959) 'K' is associated with the lifespan of the fishes. Beverton and Holt (1959) also found that the M/K values would normally range from 1.5 to 2.5. Sparre and Venema (1993) reported that since most of biological process goes faster at high temperature within a limit, natural mortality could be related to environmental temperature. The exploitation ratio estimated for *C. limbatus* is high which shows the intensity of fishing pressure on this resource. Elasmobranch populations are thought to be easily overexploited because of their relatively slow growth rates, long gestation period, and low fecundity (Holden, 1974; 1977). As apex predators in complex marine ecosystems, sharks have an important ecological role.

The present study focused on elasmobranchs, which are known to be biologically vulnerable to overfishing. Many demersal elasmobranch species are taken as bycatch in mixed demersal fisheries of Malabar in trawls, gillnets and longlines. The growing international market for shark fins is an important factor driving the expansion of shark fisheries worldwide. In India, a growing but largely informal shark fin export market has led to substantially increased pressure on shark stocks over the last few decades. Elasmobranchs being heavily targeted, this resource is at risk of being overexploited and is in need of immediate management.

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