Indian J. Fish., 56(2) : 95-101, 2009

Investigations on fishery and biology of nine species of rays in Mumbai waters

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ABSTRACT

Annual landings of rays by trawlers operating from New Ferry Wharf, Mumbai during 1990-2004 ranged from 205.7 t to 765.1 t with an average of 502.8 t constituting nearly 1 % of trawl catches. The trawling effort increased from 0.95 million hours (mh) in 1990 to 1.73 mh in 2004, whereas the catch rate declined from 0.65 kg h^{-1} in 1990 to 0.24 kg h^{-1} in 2004. There were two peak periods of abundance, September-December and February-April. Fourteen species of rays constituted the fishery, of which *Himantura alcockii* (50.1 %), *Himantura bleekari* (13.9 %), *Amphotistius imbricatus* (8.5 %) and *Himantura uarnak (8.1 %)* formed the mainstay of the fishery. Information on biology of *H. alcockii, H. bleekeri, A. imbricatus, Pastinacus sephen, Dasyatis zugei, Gymnura japonica, G. poecilura* and *Mobula diabolus* is also presented. It appears that the resource of rays off Mumbai may not be able to withstand any further increase in fishing effort. Innate biological characteristics such as limited brood size, late maturation and capture of spawning stock are the causes of continuous decline. Conservation measures are required to protect this resource from further depletion.

Keywords: Biology, Fishery, Mumbai waters, Rays

Introduction

Rays form about 11 % of the total elasmobranch catch of Maharashtra (Raje *et al*., 2002). Trawlers land 98 % of rays and the remaining are landed by gill nets and dol nets. Rays are of great commercial importance at Mumbai and are consumed in fresh, dried and salted forms. Some information is available on the breeding of rays in Bombay waters (Setna and Sarangdhar, 1949). Length-weight relationship of five species of rays and some aspects of biology of rays have been studied by Raje (2000; 2003). However, there is no information on the fishery of rays. The present investigation was taken up on the fishery and biological characteristics of rays based on the data collected during 1990 - 2004.

Materials and methods

The data for the present study were collected from commercial trawlers operating from New Ferry Wharf during 1990–2004. The number of trawling hours was estimated from the number of days of fishing undertaken by each multi-day trawler during the fishing voyage. During fishing, a multi-day trawler carries out four hauls per day and 3 hauls per night with each haul lasting for 2.5 - 3.0 h duration. The mean catch and effort for the observed units were raised to the total units landed on that day to get the days estimate and further raised to the month based on number of fishing days to get a monthly estimate. Biological data of rays such as disc width, sex and maturity status of males and females were collected from samples examined at the landing center. The clasper length of males was measured as a straight-line distance from the posterior point of the cloaca to the end of the clasper as described by Devadoss (1978). Litter size was assessed by examining the uterine contents of females of nine species of rays. All the size mentioned in the paper as length frequency, size at first maturity, size of new born *etc*, pertain to the disc width (DW).

Results and discussion

Catch and Effort

The annual average catch of rays landed by trawlers at New Ferry Wharf during 1990–2004 was 502.8 t at a catch rate of 0.35 kg h^{-1}, constituting 0.8 % of the total catch. The landings ranged from 205.7 t in 2002 to 765.1 t in 1993 (Fig. 1) whereas the annual catch rate decreased from 0.65 kg h^{-1} in 1990 to 0.24 kg h^{-1} in 2004 (Fig. 2). The annual trawling hours increased from 0.96 million hours (mh) in 1990 to 1.73 mh in 2004. The upward trend

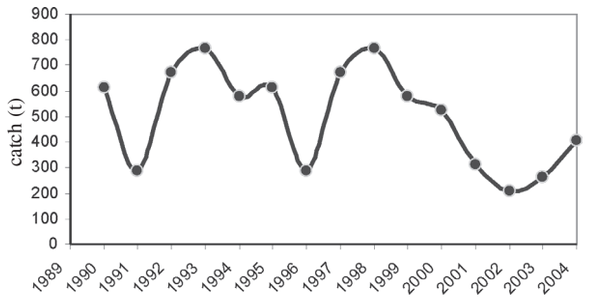

Fig. 1. Landing of rays by trawlers at Mumbai New Ferry Wharf during 1999-2004

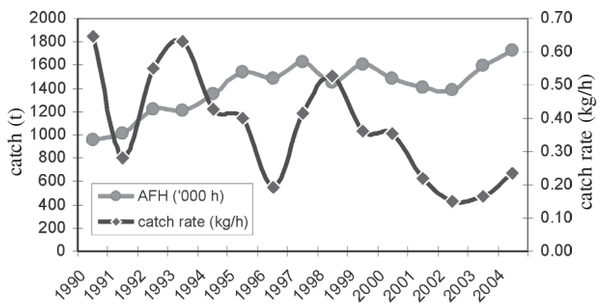

Fig. 2. Actual fishing hours (AFH) and catch rate of rays in trawlers at New Ferry Wharf during 1999-2004

of trawling hours was due to gradual increase in multi-day fishing operations. The fishing efforts in unit (number of operations) increased from 24,902 trawlers in 1990, which reduced to 21,910 units in 2004.

Seasonality of catch

Analysis of monthly catch of rays for the 15-year period (Fig. 3) reveal the occurrence of two peaks in the annual landings. The primary peak in catch and catch rate was observed during September-December (post-monsoon)

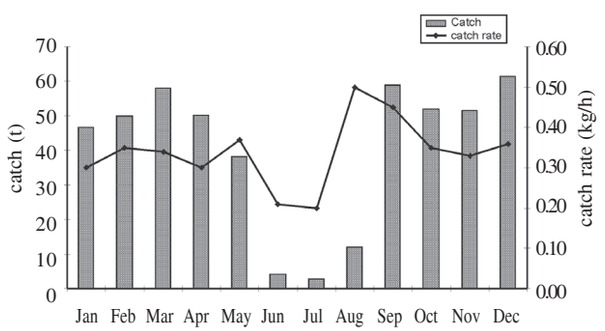

Fig. 3. Monthly average catch and catch rate of rays landed by trawlers at New Ferry Wharf during 1990-2004

and the secondary peak during February-April (pre-monsoon). The annual ray landings recorded during September-December and February-April periods were 46.1 % and 32.5 % respectively.

Species composition

The fishery of rays in the trawlers at New Ferry Wharf was constituted by eight genera. The percentage contribution by different species were: *Himantura* spp. 73.3 %, *Amphotistius* spp. 8.5 %; *Pastinacas* spp. 3.1 %; *Aetobatus* spp. 4.0 %, *Gymnura* spp. 1.9 %, *Mobula* spp. 0.7 %, *Dasyatis* spp. 0.6 %; *Rhinoptera* spp. 0.1 % and others 6.7 %.

The dominant species (Fig. 4) constituting the fishery of rays in order of abundance were *Himantura alcockii, Himantura bleekeri, Amphotistius imbricatus, Himantura uarnak, Himantura gerrardi, Pastinacus sephen, Aetobatus narinari, Gymnura japonica, Mobula diabolus, Dasyatis zugei, G. poecilura, Rhinoptera javanica, Himantura jenkinsii* and *Aetomylaeus nichofii.* The other species recorded were *Amphotistius kuhlii, Dasyatis pastinaca* and *Himantura marginatus*. Phase-wise anlaysis of the contribution of different species to the ray fishery (Fig. 5) suggest that *H. alcocki,* remained the dominant species in

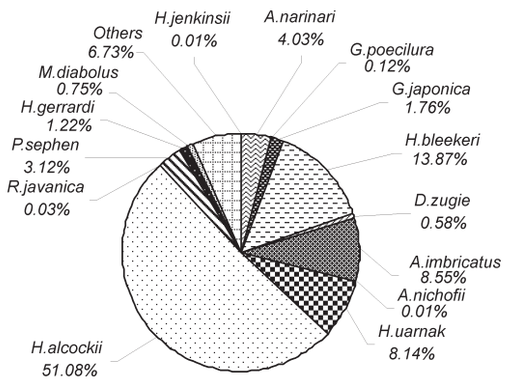

Fig. 4. Percentage composition of different species of rays in trawl net landed at New Ferry Wharf

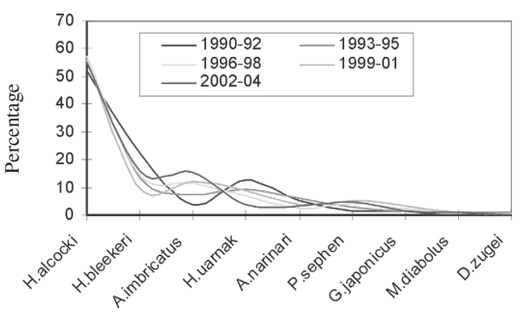

Fig. 5. Variation in percentage composition of different species of rays in the total catch of rays during different periods of study.

Table 1. Three year average landings (t) of important species of rays

Species/Years	1990 - 92	1993 - 95	1996 - 98	1999 - 01	2002 - 04	1990 – 2004 Average catch	Percentage
H. alcockii	247.7 (0.23)	371.0 (0.27)	242.4 (0.16)	240.8 (0.16)	148.0 (0.09)	250.0 (0.18)	51.08
H. bleekeri	107.2 (0.10)	87.8 (0.06)	60.5 (0.04)	41.5 (0.03	42.2 (0.03	67.8 (0.05	13.87
A. imbricatus	17.9 (0.01)	49.2 (0.04)	48.6 (0.03)	52.3 (0.04	41.0 (0.03	41.8 (0.03)	8.55
H. uarnak	60.13 (0.06)	60.5 (0.04)	29.3 -0.02	39.1 (0.03	10.1 (0.01	39.8 (0.03	8.14
A. narinari	24.4 (0.02)	38.5 (0.03	9.7 (0.01)	16.7 (0.01)	9.0 (0.01	19.7 (0.01)	4.03
P. sephen	5.8 (0.01)	17.6 (0.01)	16.9 (0.01)	22.7 (0.02)	13.2 (0.01	15.2 (0.01)	3.12
G. japonica	6.9 (0.01)	9.7 (0.01)	10.0 (0.01)	13.2 (0.01)	3.2 (0.01	8.6 (0.01)	1.76
M. diabolus	0.8 (0.01)	6.3 (0.01)	4.8 (0.01)	3.1 (0.01)	3.1 (0.01	3.6 (0.01)	0.75
D. zugie	4.5 (0.01)	7.1 (0.01)	1.4 (0.01)	1.0 (0.01	— —	2.8 (0.01	0.58
Others	48.9 (0.05)	63.2 (0.05)	33.5 (0.02)	31.6 (0.02)	21.5 (0.01)	39.7 (0.03)	8.12

Catch rate (kg h^{-1}) given in parenthesis

all the periods of study whereas percentage of *A. imbricatus* and *H. uarnak* showed fluctuations. The details on phase-wise catch, catch rate and percentage composition of important genera / species are given in Table 1.

Fishery and biology of important species

Himantura alcockii

This species was most dominant, supporting the fishery with the average annual landing of 250 t, at a catch rate 0.18 kg h^{-1} constituting 51.1 % of the ray landings. The catch decreased from 371.0 t in 1993-95 to 148.0 t in 2002-04. This species was dominant in all months when rays were landed in abundance during January–March and October-December.

Females were dominant in the fishery with a sex ratio of 1:1.7 (Table 2). The length frequency distribution of males and females showed that females attain larger size than males. The modes were at 52 and 72 cm for males and 56 and 88 cm for females. The size at first maturity for males was 58 cm and females was 63.5 cm and pregnant females were found from 64 cm in total length. The proportion of mature males (<56 cm) in the length frequency data of this species was 60.2 % and that of female (<64 cm) was 67 %. Females were dominant in the catch and percentage composition of mature males and females was more or less same. Furthermore, females in pregnant condition were observed throughout the year. The smallest mature male of *H. alcockii* with calcified claspers measured 56 cm. Males appear to approach sexual maturity at 64 cm TL (Table 2) because growth of clasper slacken at this size and all specimens larger than this had calcified claspers.

Himantura bleekeri

The average annual landing of this species was 67.8 t at 0.05 kg h^{-1} forming 13.9 % of the total catch of rays. Catch showed sharp decrease during the initial period from 107.2 t (0.10 kg h^{-1}) in1990-92 to 42.2 t (0.03 kg h^{-1}) in 2002-04. The landing of this species was more during March-May and September-December with highest in September. The overall sex ratio was 1:1 (Table 2). Females were larger in size than males. The modal class for male was at 52 cm and for females 56 cm. The smallest male in mature condition measured 51 cm and mature/pregnant females at 52 cm. The contribution of mature males (48-84 cm) in the landing was 74.7 % and females (52-100 cm) 73.9 %. Sex ratio was found to be equal and percentage contribution of mature males and females were high, which indicates that this species might aggregate at inshore waters for mating and breeding.

Males of *H. bleekeri* become sexually mature at 48 cm and elongation of the calcified clasper completed at 51 cm. This size is taken as size at first maturity for males. The males seem to mature at 51 cm. The clasper length and disc width showed a linear relationship. The logarithmtic relationship between male disc width and clasper length was

worked out as Log CL = 0.19231 + 0.501062 log DW (where CL is clasper length and DW for disc width), with an 'r' value of 0.935 indicating significant relationship.

Amphotistius imbricatus

The average annual catch was 41.8 t, at a catch rate of 0.03 kg h^{-1}. This species contributed 8.6 % to the total landings of rays. The fishery showed an increase from 17.9 t. (0.017 kg h^{-1}) in 1990 - 92 to 52.3 t (0.035 kg h^{-1}) in 1999 - 01 and then dropped to 41.0 t (0.026 kg h^{-1}) in 2002-04. The landing was better during May - July and September-December.

The sex ratio for this species was 1:1.1 (Table 2). Males had slightly shorter length than females (Table 2). The modal size classes were at 22 and 23 cm for males and females respectively. Mature males of 20-31 cm (85.1 %) and females of 22-31 cm (74.3 %) formed a good proportion of length frequency distribution. The occurrence of equal sex ratio and abundance of mature males and females suggested that they might be concentrating inshore waters for mating. In the present study, pregnant females were encountered throughout the year. Devadoss (1978) reported prolonged breeding season for this species at Porto Novo waters.

Fully calcified clasper of *A. imbricatus* was at 20.5 cm. The slack in growth of clasper appeared to be at 22.1 cm which may be considered as length of maturity for males (Table 2). Devadoss (1978) determined maturing size in respect of males of *A. imbricatus* at 160-169 mm size at Porto Novo waters.

Himantura uarnak

This species accounted for 8.14 % of the total catch of rays, with an annual average landing of 39.8 t (0.03 kg h^{-1}). During 1990-92, the catch was 60.13 t (0.06 kg h^{-1}) which decreased to 10.1 t. (0.006 kg h^{-1}) in 2002-04. The productive period for this species was July-August.

The sex ratio was 1:1.1 (Table 2). The maximum size of males was 90 cm and females 92 cm. Mature males were recorded from 85 cm onwards.

Aetobatus narinari

This species formed 4.3 % with an annual average catch of 19.7 t. The lowest catch was recorded in 2002-04 (9.0 t) and highest in 1993-95 (38.5 t). March and September recorded peak months of occurrence.

Pastinacus sephen

This species formed 3.12 % of total ray landings, with an average annual catch of 5.2 t. The landing showed increasing trend from 5.8 t in 1990-92 to 22.7 t in 1999-01 and then declined to 13.2 t in 2002-04. The productive

Table 2. Biological characteristics of selected species of rays from Mumbai.

Species	No. Examined	Disc width (cm)		Size at 1st maturity (cm)		% of size at maturity to maxm length		Sex ratio	Disc width of new born	% length of new born to mxm length	No of litters		No. of females examined	Source
		Male	Female	Male	Female	M	F		(cm)		Range	Average		
H. alcockii	1058	20 - 96	20 - 116	58	63	0.6	0.54	1 : 1.7	13.2 - 28.0	0.18	1	1	49	Present
D. zugie	269	18 - 38	20 - 40	28	30	0.74	0.75	1 : 0.7	7.5 - 7.6	0.25	2	2	3	"
H. bleekeri	1301	16 - 84	24 - 102	51	52	0.61	0.51	1: 1	--	-	1	1	17	"
H.uarnak	760	19 - 90	13 - 92	--	--			1 : 0.9	--	-	1	1	1	"
A. imbricatus	1911	15 - 30	15 - 32	20	22	0.67	0.69	1 :1.1	6.5 - 9.9	0.37	1 - 2	1.2	24	"
P. sephen	700	20 - 68	20 - 88	48	53	0.71	0.6	1 : 1.3	15.7 - 25.0	0.38	1	1	6	"
G. japonica	266	20 - 88	24 - 106	44	52	0.5	0.49	1: 1.6	15.5 - 32.0	0.37	1 - 3	1.8	6	"
G.poecilura	24	34 - 90	32 - 107	72	78		0.73	1 : 7	13.4 - 19.8	0.21	3	3 - 4	3	"
M. mobula	12	115 - 210	115 - 140	115	130	0.54	0.73	1: 2	--	-	--	--	--	"
D. uarnak	--	--	--	--	156			--	29.4 - 42.5	0.23	1 - 2	1.7	4	Setna and
D.bleekeri	--	--	--	--	101			--	15.2 - 18.7	0.17	1	1	2	Saranghdar, 1949
D.walga	--	--	--	--	23			--	4.5 - 7.5	0.26	1 - 2	1.8	5	"
G. poecilura	--	--	--	--	79			--	21.2 - 26.2	0.3	1 - 6	3.4	5	"
R. javanica	--	--	--	--	109			--	20.0 - 45.0	0.3	1	1	2	"
M. diabolus	--	--	--	--	114			--	37.5 - 40.0	0.34	1	1	3	"

periods for this species were March-May, September and December. The sex ratio was slightly biased towards the females at 1:1.3. Males were smaller in size than females (Table 2). Mature males were observed at 48 cm, mature females at 50 cm and pregnant females at 53 cm. The dominant modes were at 48 cm in males and 64 cm in females. The percentage contribution of mature males in length range of 48-76 cm was 58.7 % and females in the length range of 48-96 cm was 70.3 %. The sex ratio was found to be in favour of females and composition of mature females was highest at 70.3 %. It appeared that females might be migrating towards inshore waters for breeding. Devadoss (1998) and Raje (2003) reported prolonged breeding season for this species from Madras and Mumbai waters respectively.

The claspers of male *P. sephen* at 48 cm were found to be fully calcified. Males appear to mature when they reach 51 cm (Table 2) as the growth of claspers is slower at this size. The clasper length and disc width showed a linear relationship. The logarithmic relationship between male disc width and clasper length was worked out as Log CL =-1.49718+1.566713 log DW, with a correlation coefficient (r) value of 0.975 indicating highly significant relationship.

Gymnura japonica

With an average annual landings of 8.6 t, this species formed 1.76 % of the ray landings. The catch of this fish increased from 6.9 t in 1990-92 to 13.2 t in 1999-01, which drastically dropped to 3.2 t in 2002-04. The maximum catch was during the months of November-December.

The male:female ratio was in favour of females with 1:1.6. Females were larger in size than males. The minor mode for both the sexes was noticed at 36 cm while prominent mode for males seen at 56 cm and for females at 84 cm. In the length frequency data, mature males (44-92 cm) represent 70.2 % and females (48-104 cm) 72.2 %. The presence of both the sexes in larger proportion in mature condition in the fishery indicates that this species might be migrating to inshore waters for mating and breeding. James (1966) observed females in greater number than males and prolonged breeding period in a related species, *G. poecilura* from the Palk Bay and the Gulf of Mannar. Raje (2003) also reported similar findings in *G. micrura* from Mumbai. Mature males of *G. japonica* in smallest length measured 44 cm. The growth of clasper from 52 cm onwards appeared to be slow. Thus, this length may be taken as the length of sexual maturity.

Mobula diabolus

The landings of this species was sporadic, contributed only 0.75 % to the catch of rays with an average catch of 3.6 t. The maximum of 6.3 t recorded in 1993-95 dropped subsequently to 4.8 t in 1996-98 and remained at 3.1 t in 1999-01 and 2002-04. Maximum landing was observed during August-September. The sex ratio was 1:2. The largest specimen of male of this fish was measured at 130 cm and female 140 cm. Mature males were noticed from 115 cm onwards and pregnant females from 130 cm onwards. Setna and Sarangdhar (1949) recorded length of pregnant females at 112 cm from Mumbai.

Dasyatis zugei

The annual average catch of this species was only 2.8 t, with a poor contribution of 0.58 % to the ray fishery. The maximum catch was in 1993-95 (7.1 t), which subsequently dropped to 1.0 t in 1999-01 and catch was absent during 2002-04. The occurrence of this species was maximum in February-March. Devadoss *et al*. (2000) analysed the decade wise data on elasmobrachs collected during 1950-1990 and found that the annual average production during eighties and nineties were 57,159 t and 57,501 t respectively. They opined that substantial increase in the yield may not be possible in the present area of exploitation. The M:F ratio in *D. zugei* was 1:0.7 (Table 2). Females were slightly larger in size than males. The size frequency distribution was unimodal for males at 28 cm and females at 30 cm. Mature males (28-38 cm) dominated the fishery by 67.1 % and females by 72.2 %.

The presence of good percentage of mature males and females indicated that this species might be migrating to inshore waters for mating and breeding. Setna and Sarangdher (1948) recorded gravid females from February to April in Mumbai waters. In the present study, females in mature condition were noticed during January to July and October-November and pregnant ones during December-February, May, July and October. The clasper length and disc width showed a linear relationship. The logarithmic relationship between male disc width and clasper length was worked out as Log CL = -1.366568+1.375946 log DW with high correlation coefficient (r = 0.965).

Gymnura poecilura

The proportion of male to female was 1:7. The largest specimens of males and females recorded was 90 cm and 107 cm respectively. The pregnant females in smallest size were at 78 cm.

Litter size

Examination of the uterine contents of pregnant females of various species indicate that *Himantura alcockii* produce 1 offspring (mean litter size -1), *D. zugei* 2 (2), *Himantura bleekeri* 1 (1), *Himantura uarnak* 1 (1), *A. imbricatus* 1-2 (1.2), *P. sephen* 1 (1), *G. japonica* 1-3 (1.8) and *G. poecilura* 3 (3). Devadoss (1998) recorded

one or two young ones in *D. zugei, D. sephen, D. jenkinsii;* up to 3 embryos per litter in *A. nichofii* and up to 6 in *G. poecilura* from Madras. James (1966) recorded 1-7 young ones in *G. poecilura* from the Palk Bay and Gulf of Mannar. Setna and Sarangdhar (1949) noted brood size in *D. uarnak*: 1-2 (mean-1.7), *D. bleekari*: 1 (1), *D. walga*: 1-2 (1.8), *G. poecilura*: 1-6 (3.4), *R. javanica*: 1 (1) and *M. diabolus*: 1 (1).

Analysis of the trawl data during 1990-2004 indicated that though actual trawling hours increased, the catch of all species of rays showed declining trend. The landing of *D. zugei* drastically dropped from 7.1 t in 1993-95 to almost nil in 2004. The brood size in these rays ranged from 1 to 3 only. The biological data such as length of mature males with calcified clasper and pregnant females indicated late maturity in both the sexes (Table 2). There is preliminary evidence to suggest that because of fishing, higher numbers of mature individuals are taken out from the population of rays. Moreover, females were found to be dominant in the catches of most of the species. Percentage of size at first maturity of rays to the maximum length of males and females varied from 0.49 to 0.75 (Table 2) whereas this value generally lies below 0.5 for large pelagics, above 0.5 for small demersals and above 0.7 for small pelagics. The longer gestation period of most species of rays is evident from the comparatively bigger size of the new born; the percentage length (disc width) to maximum size of female ray varied from 0.17 to 0.36. Therefore, as suggested by Holden (1968; 1974) the pregnant females should be given considerable protection if sustainable fisheries were to be maintained.

The fact that sizes and modal lengths of females of all the species were larger is probably the result of a differential growth rate, as observed in other selachians by Ford (1921), Hickling (1930), Nair (1976), Schwartz (1983) and Devadoss (1998). Branstetter (1990) indicated that the increasing exploitation of adult stock of sharks might result in reduced future cohort strength, leading to insufficient recruitment and eventually collapse of populations of the north-west Atlantic. Pratt and Casey (1990) reported that sharks, skates and rays use coastal and estuarine areas as pupping and nursery areas in the United States. In the present study, the occurrence of mature male and female rays in inshore catches probably indicate the same.

The innate biological characteristics such as maturation of males and females noticed at higher length, limited offspring production, capture of more spawning stock of both sexes and current fishing pressure level do not support extensive exploitation. Holden (1973; 1974) observed relatively few offsprings, late maturity and slow growth in a few elasmobranchs and stated that these characteristics generally make the group vulnerable to over-fishing. The size of population and regulatory size limits would have to be established, thus providing the non-reproductive individuals an opportunity to mature and reproduce (Martin and Cailiet, 1988). Reduction in effort is highly essential to maintain the maximum sustainable yield (MSY) of elasmobranchs at most of the landing centres along the Indian coast (Devadoss *et al.,* 1989). Considerintg the limited ability of many species of rays to increase their population size, and the prolonged gestation time (Table 2), it appears that even with implementation of stringent management measures, this multi-species stock would take many years to recover (Hoff, 1990). If the fishery has to be maintained at a sustainable level, information on life history parameters should be continuously collected (Pratt and Casey, 1990). There is a need for public awareness regarding sensitivity of chondrithyans to over-exploitation (Campagno, 1990).

Acknowledgements

The authors are grateful to Prof. (Dr.) Mohan Joseph Modayil, former Director, CMFRI, Cochin for facilities, Dr. E. Vivekanandan, Head, Demersal Fisheries Division, CMFRI, Cochin and Dr. V. D. Deshmukh, SIC, Mumbai RC of CMFRI for encouragement. The sincere help provided by the technical staff, Shri. Thakurdas, B. B. Chavan, J. D. Sarang, Sujit Sundaram, J. R. Dias and Sushant Mane in the field is gratefully acknowledged.

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Date of Receipt : 27/08/08
Date of Acceptance : 11/02/09