Indian J. Fish., 69(3): 1-11, 2022
DOI: 10.21077/ijf.2022.69.3.117929-01

Catch composition, reproductive biology and diet of the bowmouth guitarfish *Rhina ancylostomus* Bloch and Shneider, 1801 (Batoidea: Rhinidae) in the eastern Arabian Sea, India

G. B. PURUSHOTTAMA, SUJITHA THOMAS, SHOBA JOE KIZHAKUDAN AND P. U. ZACHARIA
ICAR-Central Marine Fisheries Research Institute, P. O. Box 1603, Ernakulam North, P. O., Kochi - 682 018, Kerala, India
e-mail: puru44@gmail.com

ABSTRACT

Scarce information exists on the life history of the bowmouth guitarfish *Rhina ancylostomus* (=*R. ancylostoma*) landed by trawlers and gillnetters that operate in the eastern Arabian Sea off Karnataka, on the south-west coast of India. This study was carried out to update information on this species by analysing the size distribution, sex ratio, length-at-maturity ($Lm_{50\%}$), length–weight relationship and diet using data collected during 2016-2019. Three hundred and sixty-nine individuals were collected with a total length (TL) range of 44.0 to 295 cm and total weight (TW) range of 0.2 to 127 kg. The length-weight relationship (LWR) of females and males did not differ significantly and therefore, a common equation was derived as $TW = 0.006604TL^{3.027504}$($r^2$=0.979). The length-at-maturity ($Lm_{50\%}$) for females and males were estimated to be 183.0 and 164.0 cm TL, respectively. *R. ancylostoma* has two functional ovaries and the ovarian cycle and gestation run concurrently. The number of embryos ranged from 2 to 8 and size at-birth was estimated to range between 44.0 and 50.0 cm TL. Overall sex ratio indicated dominance of females. Dietary analysis of stomach contents (%IRI) revealed that *R. ancylostomus* fed primarily on teleosts (73.3%), crustaceans (20.5%) and molluscs (6.2%). Gravid females enter coastal waters possibly for parturition and feeding in some seasons, where they become vulnerable to trawl and gillnets used along Karnataka coast. The species is categorised in IUCN Red List as "Critically Endangered" and the present study revealed the urgent need to construct an effective management plan to conserve this species in the region.

Keywords: Bycatch, Elasmobranchs, Life history, Shark ray

Introduction

Shark-like batoids are highly vulnerable elasmobranchs (Dulvy *et al*., 2014; Moore, 2017; Jabado, 2018; Purushottama *et al*., 2018). Regional elasmobranch fisheries are highly dynamic and always change pattern according to consumer demand, export value, abundance of species, availability and price (Akhilesh *et al*., 2011; Nair *et al*., 2013).Therefore, studying the types of species of shark-like batoids that are landed and their biological traits are necessary prerequisite for formulating conservation measures for these species in India. The bowmouth guitarfish *Rhina ancylostomus* Bloch and Schneider, 1801 (Rhinopritiformes: Rhinidae) (=*R. ancylostoma*) is a viviparous batoid, widely distributed across Indo-West Pacific, where it inhabits the demersal, coastal and offshore reefs at depths of 3-70 m, with a preference for sand and mud bottoms and is also found in the water column (Michael, 1993; Carpenter *et al*., 1997; Compagno and Last, 1999; Last *et al*., 2016). It is classified as 'Critically Endangered' in the IUCN Red List of Threatened Species (Kyne *et al*., 2019). Although this species is often caught in the commercial fisheries in its known range of distribution, there is only limited information from some studies restricted to the Arabian Sea and Persian Gulf (Devadoss and Batcha, 1995; Raje, 2006; Jabado, 2018). Most of these studies are either anecdotal or rare observations on a few pregnant specimens or opportunistic survey and do not elicit details pertaining to life-history traits or diet. Some exceptions to these studies are that of Si *et al*. (2016) which reported the complete mitochondrial genome of *R. ancylostomus* which was clustered with *Rhinobatos* and that of Tuntivanich and Cheunsuang (2017) which described the macroscopic structure of the eye and its adnexa. Very little is known about its fishery and biology in Indian waters. Raje (2006) noted that *R. ancylostomus* is mostly landed as bycatch of shrimp trawls from north eastern Arabian Sea, with highest average landing during 1989-1993 (8.22 t), which decreased to 5.34 t in 1994-1998 and further to 3.78 t during 1999-2003. Mohanraj *et al*. (2009) observed that in Bay of Bengal, *R. ancylostomus* is not subjected to targeted fishing, the landings of which decreased from 88.7 t in 2002 to 7.4 t in 2005 and later increased to 12.6 t in 2006. Considering the decreasing trend in its landing from north-eastern Arabian Sea and lack of information on its biology and stock status in the northern Indian Ocean, the present study was carried out to elucidate information on biological characteristics of *R. ancylostomus* from the eastern Arabian Sea, along the south-west coast of India namely, size at sexual maturity, length-weight relationship, fecundity and diet.

Materials and methods

Three hundred and sixty-nine specimens of *R. ancylostomus* comprising 199 females and 170 males were collected from trawl net and gillnet landings at Mangaluru (12°51'10.8''N; 74°49'58.8''E) and Malpe (13°20'49.2''N; 74°42'3.6''E) fisheries harbours in Karnataka coast (Fig. 1) during 2016-2019. Fishing operations were carried out between 5 and 85 m depth in the eastern Arabian Sea off Karnataka.

All specimens were measured for total length (TL, cm) and the total body weight (TW, kg). The sex of each specimen was recorded. The umbilical scar was categorised from the healing status *i.e.,* open, healing, or closed. Based on the state of the umbilical scar, as well as the TL, the individuals with opened and healing umbilical scars were classified as neonates, while the ones with closed scars were identified as juveniles.

The estimates of landings of elasmobranch resource groups were accessed from the National Marine Fishery Resources Data Centre (NMFDC) of the ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI).

The size distribution (with 20.0 cm class intervals) for each sex was subjected to Shapiro-Wilk test (Shapiro and Wilk, 1965) to ascertain deviation from normal distribution. Based on the result, sex-based size differences were tested using a two-tailed *t*-test. Sex-wise differences in the size distribution was ascertained using χ^2 test (Cochran, 1952). Sex ratios were also tested across seasons: pre-monsoon (February-May), monsoon (June-September) and post-monsoon (October-January).

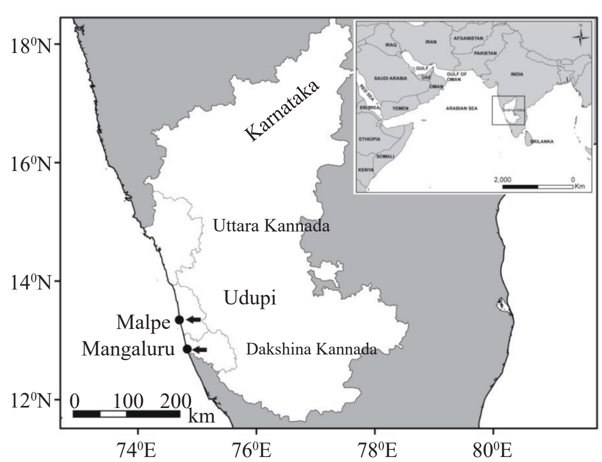

Fig. 1. Map of Karnataka indicating the locations where samples of *R. ancylostomus* were collected

Maturity stages were classified following the maturity scale proposed by Stehmann (2002). In females, the state with undeveloped ovaries or ovaries with maturing oocytes and thin, ribbon-like uteri were considered immature while those with fully developed ovaries and uteri were considered mature. In males, the extent of calcification of the claspers was assessed. Those with partially calcified claspers were considered immature while those with well calcified claspers were categorised as mature. For embryos, the mean embryonic TL (measured to the nearest millimeter) was compared for each month. Fecundity was assessed from the number of uterine embryos in each pregnant female. Difference in litter size between left and right uteri was tested for statistical significance using t-test. In males, the relationship between clasper length and body size was studied by comparing the outer clasper length (OCL) and TL of each individual.

The $Lm_{50\%}$ for both sexes was derived by logistic regression, using the equation $pL = \{1 + e^{[-\ln(19)(TL-TL_{50})(TL_{95}-TL_{50})]-1}\}^{-1}$ where pL is the proportion of mature fishes at a given length (TL), while TL_{50} and TL_{95} are constants. The SOLVER routine in Microsoft™ Excel was used to derive maximum likelihood estimates of the parameters where likelihood of immature and mature individuals was calculated as 1 - pL and pL, respectively. The c. 95% C.I. was estimated as 2·5 and 97·5 percentiles of 200 estimates derived from re-sampled data (Wood, 2004; White, 2007; Purushottama *et al.,* 2017). The distribution of juveniles, sub-adults and adults of both sexes based on $Lm_{50\%}$ was also analysed.

Length-weight relationship (LWR) was estimated using the exponential equation $TW=a*TL^b$ (Le Cren, 1951) after logarithmic transformation, TW being the weight of the fish in g and TL the total length in cm; *a* the intercept and *b,* the regression coefficient (Froese, 2006). The confidence and prediction intervals were calculated as per Montgomery *et al*. (2012). Sex-wise difference in LWR was tested for statistical significance by analysis of covariance and the *F*-test (Montgomery *et al*., 2012).

Analysis of diet was done to estimate the percent Index of Relative Importance (%IRI) as IRI=(%*N* +%*M*)* %*O*, where *O* is the frequency of occurrence, *N* is the composition by number and *W* is the percent composition by mass (Pinkas *et al*., 1971). Expression of IRI as % IRI allowed comparison between the prey groups (Cortes, 1997).

Results

The landings of wedgefish and guitarfish species in India over the past >3 decades indicated a marginal increase from an annual average 2,364 t in 1985-1994 to 2,936 t in 2010-2019. Trawls caught ~73% of wedgefish and guitarfish in India; bottom-set gillnets ~17%, artisanal gears ~6% and hook and lines landed ~3%. Although wedgefish and guitarfish formed ~1% of total marine fish landings in India, these species are socio-ecologically important in coastal waters. At present, more than twelve described species of Rhinidae, Rhinobatidae and Glaucostegidae are harvested from nine maritime states of India, which contributed on an average 6% (2007-2019) to the total catch of elasmobranchs (Table 1). *R. ancylostomus* were caught more on the west coast (76%) than on the east coast (24%) and contributed only ~1.0% to the total catch of all batoidea from Indian waters.

Commercial trawls, gillnets and occasionally artisanal gears land bowmouth guitarfish as bycatch along Mangaluru and Malpe in Karnataka region throughout the year, except during rough sea conditions in the south-west monsoon period when there is also a ban on mechanised fishing implemented by the Government of India uniformly along the west coast, from 01 June to 31 July. The estimated average annual landing (2007-2019) of *R. ancylostomus* by shrimp trawlers, gillnetters and artisanal gears together in Karnataka was 81 t. The landing was higher in 2010 (228 t) and 2011 (158 t), which decreased drastically to 10 t in 2017 and 5 t each in 2018 and 2019. *R. ancylostomus* contributed 61% of the wedgefish and guitarfishes landed in Karnataka during 2007 to 2019.

Sex and size distribution

A total of 369 specimens in the length and weight range of 44.0-295.0 cm TL (mean±S.D. = 117±58 cm) and 0.2-127 kg body weight (mean±S.D. = 15±22 kg) were used for the study. Of this, 54% were females and 46% were males indicating a sex ratio slightly skewed in favour of females (χ^2[1, n = 369] = 2.28 p>0.05). However, the overall sex ratio (F:M) in the landings (1.2:1) did not deviate significantly (p>0.05) from the hypothetical ratio of 1:1 (Table 2). The seasonal sex ratio was 1.1:1 in both pre-monsoon and monsoon seasons and 1.2:1 in post-monsoon season. Monthly sex ratio too did not show significant difference between sexes (χ^2, d.f. = 9, p>0.05). The female guitar fishes ranged in size between 44.0 and 295.0 cm TL (mean±S.D.= 118±63 cm) and 0.2 and 127 kg weight (mean±S.D. = 16±26 kg) while males were in the size range of 45.0 to 235.0 cm TL (mean±S.D. = 116±52 cm) and 0.2 to 81.5 kg weight (mean±S.D. = 14±17 kg) suggesting a higher maximum size in females. The monthly length frequency distribution (pooled for all the years) present a clear trend of sex-wise size distribution (Fig. 2a-j), across 14 size groups of 20 cm class interval (Fig. 3). The χ^2 test revealed no significant difference (p>0.05) between the sexes with higher occurrence of both females and males in the same length range of 65 -125 cm TL.

There was significant difference in the sex-wise distribution of juveniles (<100 cm TL), sub-adults

Table 2. Monthly sex ratio of *R. ancylostomus* in Karnataka, south-west coast of India

Month	Sex ratio (F:M)	χ^2	p
January	1.3:1	0.69	0.41
February	1.6:1	3.56	0.05*
March	0.7:1	1.45	0.23
April	1.1:1	0.03	0.87
May	1.2:1	0.38	0.54
August	1.8:1	0.82	0.37*
September	0.6:1	0.50	0.48
October	0.7:1	0.62	0.43
November	1.1:1	0.13	0.72
December	2.7:1	4.55	0.03*

*Significantly different

Table 1. Summary of group-wise elasmobranch landings and *R. ancylostomus* bycatch (t) during 2007-2019 in Indian waters

Year	All India elasmobranchs production			Total	Batoidea	All India *R. ancylostomus* production			Karnataka	
	Sharks (A)	Rays (B)	Wedgefish and Guitarfishes (C)	(A+B+C)	(B+C)	East coast (D)	West coast (E)	Total (D+E)	Wedgefish and Guitarfishes	*R. ancylostomus*
2007	28159	16402	2950	47511	19352	59	561	620	129	68
2008	25675	18246	3530	47451	21776	6	656	662	143	80
2009	29126	20980	3582	53688	24562	15	81	96	122	41
2010	20245	18095	2326	40666	20421	7	240	247	246	228
2011	26746	24017	2706	53469	26723	12	175	187	236	158
2012	22537	27802	2263	52602	30065	9	138	147	202	117
2013	21138	22986	2347	46471	25333	19	188	207	171	113
2014	22479	22334	2471	47284	24805	160	128	288	146	111
2015	23595	26835	2004	52434	28839	102	3	105	186	74
2016	23002	26211	3627	52840	29838	26	80	106	46	41
2017	19777	17766	2628	40171	20394	48	64	112	33	10
2018	21154	17223	3740	42117	20963	186	19	205	61	5
2019	17584	25545	3995	47124	29540	72	6	78	10	5
Avarage	23171	21880	2,936	47987	24816	55	180	235	133	81
%	48	46	6.0	--	--	24	76	1.0	--	61

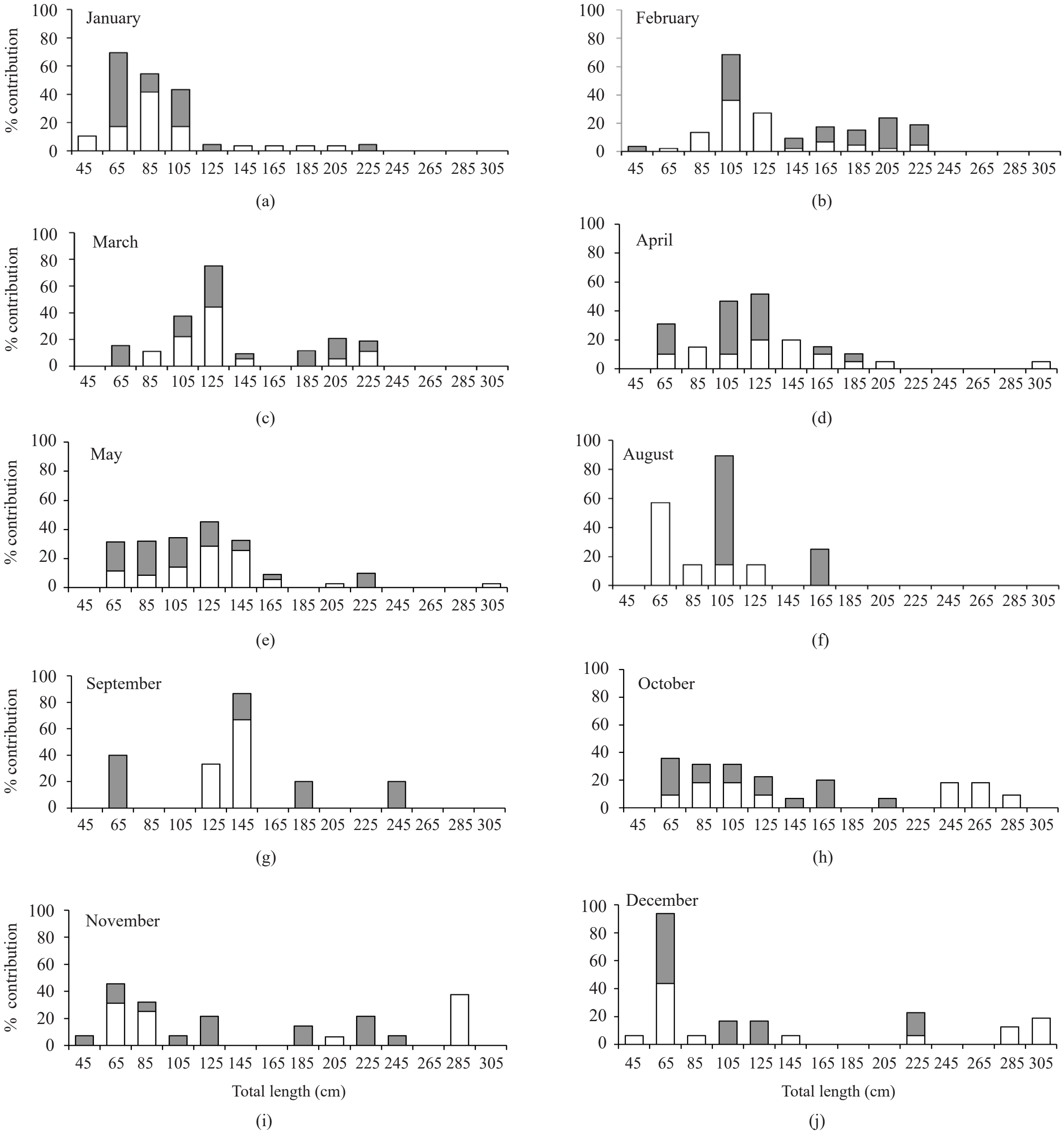

Fig. 2. Pooled monthly length frequency distribution of females (□)and males (■) of *R. ancylostomus* from Karnataka (January 2016-December 2019)

(101-182 cm TL) and adults (>183 cm TL) (χ^2, d.f. = 2, $p<0.05$), with female to male sex ratios of 1.1:1, 1.7:1 and 0.7:1, respectively.

In females, occurrence of juveniles was maximum in February (25%), January (23%) and May (12%), that of sub-adults in May (28%) and February (23%) and that of adults in November (34%), December (21%) and October (17%) [Fig. 4(a)]. In males, juveniles were observed during January-May with peaks in January and May (23%), sub-adults occurred more in March (21%) and April and May (17%) and adults, during February-March and November with peak occurrence in February (33%) [Fig. 4 (b)].

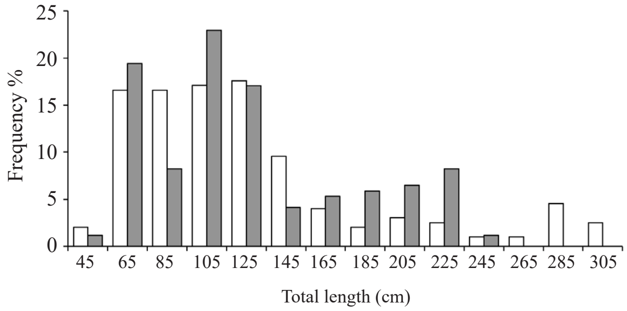

Fig. 3. Pooled annual length frequency distribution of *R. ancylostomus.* Females (□), *n* = 199; Males (■), *n* =170 from Arabian Sea off Karnataka (January 2016-December 2019)

Length-weight relationship (LWR)

The LWR estimated were:

Females: TW = 0.009003 $TL^{2.960941}$ (r^2 = 0.982, 95% C.I. of *b*= 2.801529 - 3.120352, *n* = 199)

Males: TW = 0.005467 $TL^{3.112696}$ (r^2 = 0.978, 95% C.I. of *b* = 2.860903 - 3.271491, *n* = 170)

Pooled: TW = 0.006604 $TL^{3.027504}$ (r^2 = 0.979, 95% C.I. of *b* = 2.902085 - 3.152924, *n* = 369)

The LWR for males and females did not differ significantly (*t*-test, d.f. = 367, p>0.05). The average length and weight of females did not differ significantly across months (χ^2, d. f. = 9, p>0.05).

Reproductive biology

A total of 369 (females = 199; males = 170) samples were analysed for reproductive biology. Ovarian fecundity in mature females ranged between 2 and 10 (mean±S.D. 5.0±2.0), with oocytes measuring 6.9-42 mm (mean±S.D. 27.0±8.0) in diameter. Specimens in the length range of 193.0 to 294.0 cm TL were found to have functional uteri. The smallest mature female measured 178 cm TL and the largest immature female 201 cm TL. Female *R. ancylostomus* were observed to mature between 180 and 190 cm TL, with 50% of the individuals being mature at 183.0 cm TL (95% C.I.) [Fig. 5(a)].The smallest mature and largest immature males measured 142 and 210 cm TL, respectively. Males matured in a smaller size range (160-170 cm) and $Lm_{50\%}$ was estimated at 164.0 cm TL (95% C.I.) [Fig. 5(b)].

The claspers of male *R. Ancylostomus* elongate and become rigid at ~160 cm TL and most of the examined samples >170 cm TL had fully calcified claspers. Size of maturity classes for mature (adult) (22.9%, *n*=39) males were >164 cm TL; <100 cm TL (49.4%, *n*=84) for juveniles and between 101-163 cm TL for sub-adults (27.6%, *n*=47) . Size of mature (adult) females (14.6%, *n*=29) were >183 cm TL; <100 cm TL (45.7%, *n*=91) for juveniles and between 101-182 cm TL (39.7%, *n*=79) for sub-adults. The classification was done based on 50% maturity ($Lm_{50\%}$).

Twenty-nine pregnant females of *R. ancylostomus* (193.0-295 cm TL; mean±S.D. = 249±38 cm) were observed in the samples. The pregnant females had two to eight (mean±S.D.= 5.0±1.2) fully developed embryos of 40.0-45.0 cm TL (mean±S.D. = 42.0±1.5 cm), weighing between 150.0 and 200.0 g (mean±S.D. = 170±19 g). Aplacental viviparity was noted in *R. ancylostomus*. The distribution of pregnant *R. ancylostomus* across size groups is presented in Fig. 6. Pregnant females were observed in all the months except during August and September; the species possibly has a non-seasonal reproductive cycle. Highest number of gravid females was seen in the 205.0-215.0 cm TL and 275.0-295.0 cm TL size classes (Fig. 7). Near-term foetuses (11.0-39.0 cm TL) had yolk-sac stalk still attached to them, while the late term (near to parturition) foetuses (43.0-45.0 cm TL) were found with an umbilical scar. The smallest specimen observed in

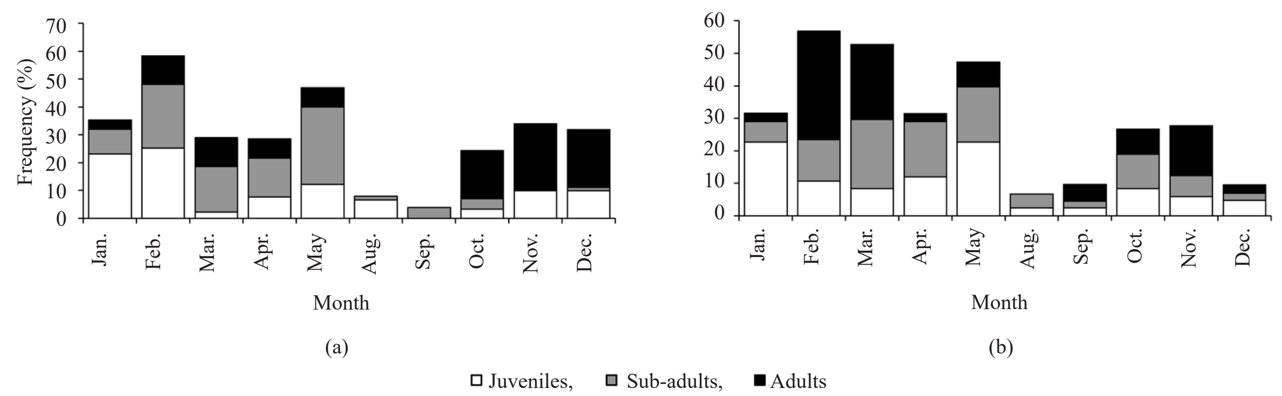

Fig. 4. Monthly frequency of occurrence of *R. ancylostomus* sampled from Karnataka between January 2016 to December 2019 (Pooled data) for (a) Female and (b) Male

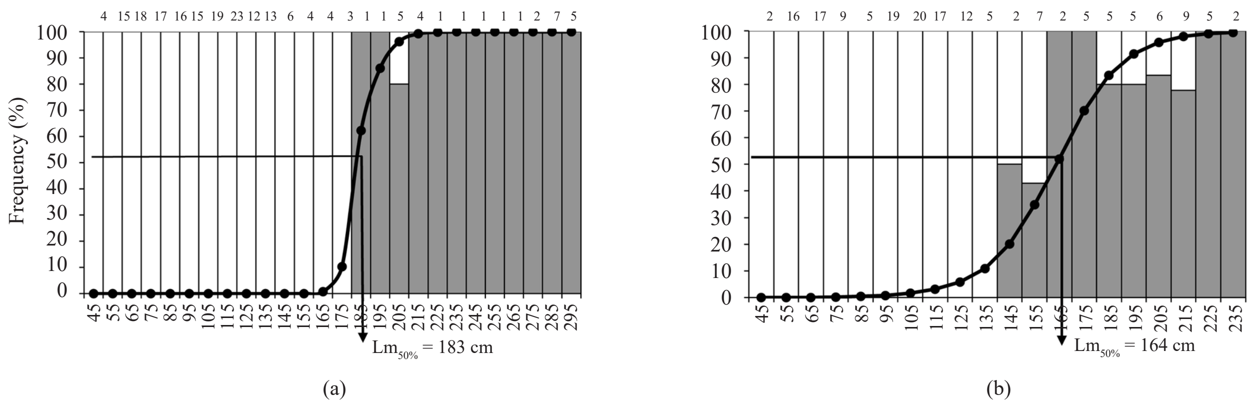

Fig. 5. Length at maturity of *R. ancylostomus* (a) female and (b) male. Numbers above each bar indicate sample size in each length class. Arrow indicates the length at which 50% of the individuals are mature ($Lm_{50\%}$)

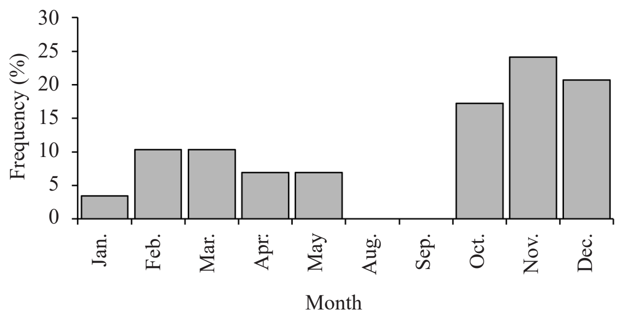

Fig. 6. Percent frequency of occurrence of pregnant females of *R. ancylostomus*

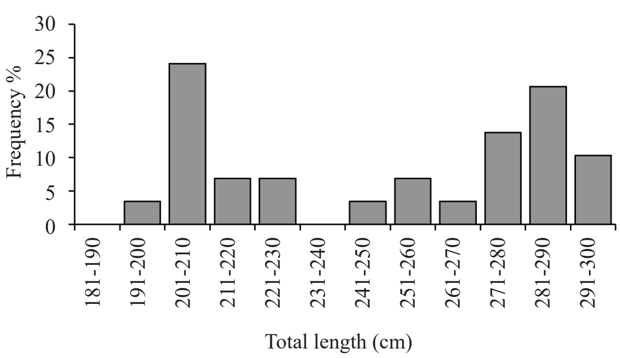

Fig. 7. Total length (TL) frequency histogram of pregnant *R. ancylostomus*

the fishery was 44 cm in TL. Trawlers landed a number of new-borns of 44-50 cm TL while the numbers observed in the gillnet landings were very low. Based on the current dataset, the size-at-birth of *R. ancylostomus* in the eastern Arabian Sea, off south-west coast of India was estimated to be 44-50 cm TL. The greatest number of embryos, *i.e.*, 8 (4 each in the left and right uteri) of mean size 44 cm TL and sex ratio of 2.0:1 (female:male) was recorded in a female *R. ancylostomus* measuring 255 cm TL and weighing 73 kg.

Sex ratio of embryos was 1.3:1 (*n*=148) estimated from 29 gravid females and did not show significant difference from parity (d.f. = 1, p>0.05). The largest female embryo observed was of 44.0 cm TL and largest male embryo encountered was of 45.0 cm TL. The OCL was found to increase with body size; the smallest male of 45.0 cm TL had OCL of 1.0 cm while the largest male of 235.0 cm TL had OCL of 41.1 cm (Fig. 8).

Feeding habit

Of the 369 specimens observed, only 29% (*n*=107) contained prey items which were analysed for the index of relative importance (IRI), 17% (*n*=61) contained food that was either in a semi-digested state or were only in trace amounts and could not be identified and 54% (*n*=201) were empty. The fullness of the stomach was calculated based on the prey items which were analysed for the Index of Relative Importance (*n*=107) and found that 57% (*n*=61) were a quarter full, 25% (*n*=27) were half full and 18% (*n*=19) were full. Identifiable prey items were found in *R. ancylostomus* specimens of both sexes in the

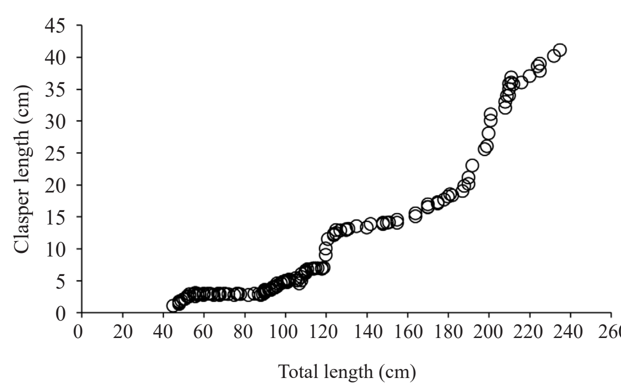

Fig. 8. Relationship between outer clasper length (OCL) and total length of males of *R. ancylostomus*

length range of 130-295 cm TL. The analysis of stomach contents indicated that *R. ancylostomus* fed primarily on teleosts (73.3%), crustaceans (20.5%) and cephalopods (6.2%). The major prey items included *Cynoglossus* spp. (%IRI=12.5), *Parapenaeopsis stylifera* (%IRI=9.3), *Johnius* spp. (%IRI=7.6), *Johnieops* spp. (%IRI=6.0) and *Stolephorus* spp. (%IRI=4.4) (Table 3).

Discussion

There is a paucity of information on the biology of *R. ancylostomus* from Indian waters as it is rarely observed and reported in the fishery. It formed on an average >5.8 t yr^{-1} in landings along the west coast of India during 1989-2003 and 32.1 t yr^{-1} in east coast of India during 2002-2006 (Raje *et al*., 2007; Mohanraj *et al*., 2009). The species has been reported to contribute only minimally to the fishery from other areas too. Roy *et al*. (2013, 2014) reported the landings of *R. ancylostomus* as 0.09 and 1.87 million t during 2011-2012 and 2006-2010, respectively in Bay of Bengal, Bangladesh. White and Dharmadi (2007) noted that the species constituted 1.5% of the total batoid biomass observed at various landing sites in eastern Indonesia between 2001 and 2006. The data on the size distribution of *R. ancylostomus* observed in the trawl/gillnet/artisanal fishery of eastern Arabian Sea (44.0-295 cm TL) differs slightly from data reported from other regions. Venkateswaralu (1967) and Devadoss and Batcha (1995) examined a single juvenile specimen measuring 54.5 cm TL and a pregnant specimen measuring 236.0 cm TL containing nine embryos in mid-term developing stage with yolk sac (26.8-31.0 cm TL), respectively, from east coast of India. Raje (2006) observed a few specimens (180-210 cm TL for females, *n*=2 and 140 cm TL for males, *n*=1) in Mumbai waters. White and Dharmadi (2007) in eastern Indonesia recorded both sexes of eighty-five specimens measuring 83.1-250 cm TL. Borell *et al*. (2011) sampled two specimens measuring 200-215 cm TL (*n*=2) in Gujarat waters. Moore *et al*. (2012) recorded a female specimen measuring 180 cm TL from Abu Dhabi waters, Roy *et al*. (2014) recorded forty-three specimens in Bay of Bengal, Bangladesh waters but did not provide information on length range and sex. Jabado (2018) recorded 114.1-223 cm TL range for females (*n*=13) and 86.6-294 cm TL range for males (*n*=41) in UAE Gulf waters and Oman and the study represented a new size record for this species compared with previously reported 270 cm TL (Last *et al*., 2016). The present study recorded maximum lengths of 295 and 235 cm TL for female and male *R. ancylostomus*, respectively, which are new size records for the species to date. However, Vidthayanon (2005) did opine that this species can attain maximum length up to 300 cm TL. The size distribution of *R. ancylostomus* in the present study emphasises the wide size range of individuals landed and implies that fisheries in the eastern Arabian Sea are possibly impacting this species across a wide range of age classes.

Table 3. Prey composition of *R. ancylostomus* from Karnataka, south-west coast of India

Prey items	% N	%M	% O	% IRI
Crustacea				
Acetes spp.	13.1	2.3	0.9	0.8
Nematopalemon tenuipes	17.0	0.4	0.6	0.6
Oratosquilla spp.	4.0	0.2	2.9	0.8
Solenocera spp.	3.3	2.6	2.9	1.1
Parapenaeopsis stylifera	3.4	13.3	9.1	9.3
Parapenaeopsis sculptilis	2.2	0.5	4.4	0.7
Others				
Unidentified Crabs	9.9	3.8	4.4	3.7
Peneaid shrimps	6.5	0.3	5.6	2.3
Digested shrimps, (unidentified)	3.1	1.3	4.4	1.2
Mollusca				
Cephalopoda				
Loligo spp.	5.9	0.3	4.4	1.7
Unidentified cephalopoda	3.5	10.2	4.4	3.7
Bivalves	2.4	1.5	3.5	0.9
Teleosts				
Johnius spp.	2.6	11.5	8.8	7.6
Johnieops spp.	3.1	12.8	6.2	6.0
Stolephorus spp.	10.3	0.8	6.5	4.4
Cynoglossus spp.	17.8	0.4	11.2	12.5
Coilia spp.	1.1	3.8	2.4	0.7
Others				
Digested fish (unidentified)	5.6	34.0	17.4	42

The present study indicated that while overall sex ratio of females to males in the fishery did not deviate significantly from the hypothetical ratio of 1:1 (Table 2), seasonal and size class sex ratio of sub-adults and adults of *R. ancylostomus* showed differences. Raje (2006) observed that females and males were not equally distributed in the fishery from north-eastern Arabian Sea during 1989-2003, with a sex ratio of 3:1. Jabado (2018) recorded that Rhinopristoids in the multi-gear regime operating in Arabian Sea and adjacent waters was comprised of more or less equal females and males (1.16:1) in the landings, which is in agreement with our results. In contrast, Moore and Peirce (2013) recorded the sex ratios for *Rhynchobatus* cf. *djiddensis* and *Rhinobatos* cf. *punctifer* (Rhinopristiformes) as 2.5:1 and 1:5 (males: females), respectively, in Bahrain waters. White and Dharmadi (2007) found that the sex-ratio was tilted towards females in *Rhynchobatus australiae* (4.15:1), *Dasyatis* cf. *kuhlii* (1.48:1), *Gymnura poecilura*, *Dasyatis zugei* (1.28:1), *Himantura jenkinsii* (1.97:1) and *Pteroplatytrygon violacea* (2.67:1) in a study of batoids in eastern Indonesia. Similarly, *Rhinobatos jimbaranensis* showed skewed sex ratio (1.4:1) with female dominance in the landings, whereas that of *Rhinobatos penggali* was 0.97:1 (White and Dharmadi (2007). Stobutzki *et al*. (2002)

also observed a dominance of females in *R. djiddensis* (=*australiae*) landed as bycatch in the northern Australian shrimp trawl fishery. Stobutzki *et al*. (2002) observed that the bycatch of *R. djiddensis* (=*australiae*) in the northern Australian shrimp trawl fishery comprised significantly more females than males. Comprehensive information on sex ratios in provincial fishery/populations of *R. ancylostomus* throughout its known range is required to determine any real trends in sexual segregation. These differences in landed size-frequency and sex ratios could be the result of several factors such as sexual or spatial segregation (Sims, 2005) or geographical fishing locations, fishing gear selectivity and/or sample size (Henderson *et al*., 2007; Mucientes *et al*. 2009; Wearmouth and Sims, 2010; Purushottama *et al*., 2017, 2020; Jabado, 2018) and regional differential growth depending on habitat (Motta *et al*., 2005), water temperature (Kock *et al*., 2013), sex-specific vertical and horizontal migration into inshore waters associated with reproduction, feeding, competition and seasonal changes (Ford, 1921; Steven, 1933, Springer, 1967; Klimley, 1987; Stevens and Mcloughlin, 1991). However, delineating elasmobranch sex distribution based on data from commercial landings may not always provide a correct trend as it may be influenced by a number of factors, including natural segregation, which is a general characteristic of elasmobranchs (Moore *et al*., 2012).

Data from 369 individuals [female, *n*=161 (44.0-295.0 cm TL and 0.35 to 127 kg), male, *n*=158, (45.0-235.0 cm TL and 0.25 to 81.5 kg)] were used to establish the relationships between length and weight (TL *vs.* TW) of *R. ancylostomus*. In this study, the smallest individual measured was 44 cm TL, weighing 0.35 kg among females and was of 45 cm TL, weighing 0.25 kg among males. The length-weight relationships did not differ significantly between the sexes (b~3). Devadoss and Batcha (1995) also reported that no significant difference was found between the sexes in length-weight relationship of this species.

The $Lm_{50\%}$ of females at maturity determined in the present study was 183 (180-190) cm TL for *R. ancylostomus*. Information on the length-at-maturity for females of *R. ancylostomus* is limited. Raje (2006) observed that females of 180 cm TL were mature, while Jabado (2018) on studying the Rhinopristoids landingsin UAE waters, recorded mature females (72.4%) assuming that maturity occurs at ~180 cm TL. Known estimates of size at maturity for females from Last *et al*. (2016) were also compared to ascertain their maturity levels.

There is not much data on length-at-maturity of male *R. ancylostomus*. The smallest adult male observed in the present study was 142 cm TL, while the smallest adult male observed by Jabado (2018) was 133.2 cm TL. Twenty four male specimens recorded were in the length range of 133.2-294.0 cm TL and had fully developed claspers. The $Lm_{50\%}$ of males estimated in the present investigation was 164.0 (160-170) cm TL, but Last *et al*. (2016) suggested that males mature at 150-175 cm TL. Therefore, the current information is the first account on size-at-maturity of male *R. ancylostomus* from Indian waters. The present study indicated that females and males mature between 160 and 180 cm TL, with males likely to mature at a smaller size.

The species had a mean litter size of 5 (ranging between 2 and 8) and the size at-birth ranged between 43 and 45 cm TL. Devadoss and Batcha (1995) observed a single pregnant female measuring 236 cm TL with nine mid-term embryos with yolk sac (26.8-31.0 cm TL). Raje (2006) examined the maturity status of two female *R. ancylostomus* and found two to eleven embryos. The present study recorded neonates with fresh, unhealed umbilical scar measuring 44 cm TL and 50 cm TL (healed umbilical scar) in the fishery.

Since, pregnant females examined in all the months except August and September contained a wide range of embryonic developmental stages, *i.e*. from fertilised eggs to late-term embryos and near-term embryos this species appears to have a non-seasonal reproductive cycle. The monsoon and post-monsoon months appear to be most conducive for reproductive activity among Rhinopristoids in Indian waters, as maximum gravid or parturient females have been observed during October to December (Raje, 2006). Raje *et al*. (2007) reported the peak breeding season for this species as September in the north-west coast of India and March in the Coromandel coast of India.

Very few studies have documented information on the dietary preferences of this species. From the present study, *R. ancylostomus* in the northern Indian Ocean is ichthyophagous, feeding primarily on teleosts (73.3%), crustaceans (20.5%) and cephalopods (6.2%). The major prey included *Cynoglossus* spp. (%IRI=12.5), *Parapenaeopsis stylifera* (%IRI=9.3), *Johnius* spp. (%IRI=7.6), *Johnieops* spp. (%IRI=6.0) and *Stolephorus* spp. (%IRI=4.4). This fish-based diet is similar to diet reported by Raje (2007), who found that *R. ancylostomus* fed on fishes (sciaenids, *Harpadon nehereus*), crustaceans (shrimps) and mollusc (cephalopods and bivalves). Devadoss and Batcha (1995) based on the characteristics of body and colour pattern of *R. ancylostomus*, opined that the food items are crab, shrimps, squilla and other crustaceans. Borrell *et al*. (2011) reported that this species feeds at the lowest trophic level (TL=3.18) (bottom crustaceans and molluscs) in north-eastern Arabian Sea. The present study indicated *R. ancylostomus* to be a mesopredator exhibiting both benthic and demersal feeding behaviour with a vertebrate-dominant diet and it plays a fundamental role in the food chain.

In conclusion, the impact of fishing pressure on elasmobranchs can range from changes in population size structure, biological characteristics and species abundance (Walker, 1998; Jabado, 2018) and benthic coastal communities (Stevens *et al*., 2000). Paucity of information on the occurrence of *R. ancylostomus* in the fishery, insufficient sample size and limited data on biological characteristics are major hiccups in gaining a proper assessment of the status of this species in many regions. However, available essential information on fishery trends, population sizes, life-history, ecology and distribution data of *R. ancylostomus* is seldom being used for making any assessment or management recommendations (Raje *et al*., 2007; Jabado, 2018). The present study adds to existing information on the occurrence, fishery and biology of *R. ancylostomus* off the south-western Indian coast. The study clearly indicates that neonates, juveniles and pregnant females are impacted by fishing activities along the south-western coast of India. The occurrence of pregnant females in the landings indicates their use of inshore areas for breeding, feeding and nursery, putting them at high risk of being impacted by fishing, pollution and damage to natural habitat from coastal development (*i.e.* dredging, shipping industry and tourism)

Since a multi-gear and multi-species fishery is practised in Indian waters, species-specific conservation or management plans are limited. However, India has imposed a ban on shark fin trade and protected 10 species of sharks, wedgefish and guitarfishes and rays included under Schedule 1 of the Indian Wildlife (Protection) Act of 1972 and trade of species listed in CITES appendices (Kizhakudan *et al*., 2015), The broad-spectrum trawl bans and finning bans, as well as regional fisheries management plans derived for the conservation of fishery resources also probably benefits this species but these regulations are hampered by limited capacity for monitoring and enforcement. Of late, awareness and conservation programmes on release of captured large size elasmobranchs have been promulgated along the Indian coast (CMFRI, 2015; 2016a,b; 2018; 2019). However, there is no data available on number of individuals released back to sea and their post-release mortality (CMFRI, 2019).

In south-eastern coast of India, under the coastal habitat enhancement, restoration and conservation programmes that were initiated over a decade ago, artificial reef structures were deployed on generally featureless seabeds to create a substratum to support a variety of marine life or where existing natural reefs have been destroyed, which serves as rich ecological niche for the purpose of recreational fisheries, disaster management, coastal protection, marine biodiversity, increasing fish catch and preventing trawling. These artificial habitats have been observed to support several species of elasmobranchs and other commercially important fishes (CMFRI, 2019). During regular survey of the artificial reefs at many sites, several endangered, threatened and protected (under the Indian Wildlife Protection Act, 1972) species of elasmobranchs like the whaleshark, *Rhincodon typus*, sting rays and guitarfishes have been observed, indicating the use of these habitats as sanctuaries (Shoba Joe Kizhakudan, *pers. observ.*). Continuous monitoring of catch in mechanised, motorised and artisanal gears, awareness generation among stakeholders, interviews with fishermen, traders and consumers to understand the dynamics of demand and supply of elasmobranchs in domestic and international trade and capacity building of stakeholders in field identification of large and endangered or threatened elasmobranchs are picking up pace (CMFRI, 2013; 2014; 2015; 2016a, b; 2018; 2019) which will serve in drawing up effective conservation measures for elasmobranchs in the region. The results of the present study will contribute in developing region-specific and species-specific measures to discourage unwarranted fishing of neonates, juveniles and pregnant individuals of *R. ancylostomus* and help to conserve the species in Indian waters.

Acknowledgments

Authors are thankful to the Director, ICAR-CMFRI, Kochi and Dr. Prathibha Rohit, Scientist In-Charge, ICAR-CMFRI, Mangaluru for the support and the facilities provided. Mr. G. D. Nataraja, Mr. U. Jeyaram, Mrs. Sathyavathi, Mr. B. Shrinath, Mr. L. B. Dharamaraju, Mr. Sujith Kumar, Mr. Nagaraj S. Gond and Mr. Naveen Raju K. G. Naik, ICAR-CMFRI, Mangaluru are acknowledged for the support in the field and laboratory. We thank the fishers and traders who allowed for data to be collected along Karnataka coast and for their friendship, cooperation and support. This work has been supported by the Indian Council of Agricultural Research, Ministry of Agriculture and Farmers Welfare, Govt. of India through CMFRI under the project codes FISHCMFRISIL201200500005 and DEM/ELS/11.

References

Akhilesh, K. V., Ganga, U., Pillai, N. G. K., Vivekanandan, E., Bineesh, K. K., Shanis, C. P. R. and Hashim, M. 2011. Deep-sea fishing for chondrichthyan resources and sustainability concerns - A case study from southwest coast of India. *Indian J. Mar. Sci.*, 40(3): 347-355.

Borrell, A., Cardona, L., Kumarran, R. P. and Aguilar, A. 2011. Trophic ecology of elasmobranchs caught off Gujarat, India, as inferred from stable isotopes. *ICES J. Mar. Sci.*, 68(3): 547-554. https:// doi: 10.1093/icesjms/fsq170.

Carpenter, K. E., Krupp, F., Jones, D. A. and Zajonz, U. 1997. Living marine resources of Kuwait, eastern Saudi Arabia, Bahrain, Qatar and the United Arab Emirates. *FAO species identification field guide for fishery* *purposes.* Food and Agriculture Organisation of the United Nations, Rome, Italy, 293 pp.

CMFRI 2013. *Annual report 2012-13*. ICAR-Central Marine Fisheries Research Institute, Kochi, India, 200 pp.

CMFRI 2014. *Annual report 2013-14*. ICAR-Central Marine Fisheries Research Institute, Kochi, India, 274 pp.

CMFRI 2015. *Annual report 2014-15.* ICAR-Central Marine Fisheries Research Institute, Kochi, India, 353 pp.

CMFRI 2016a. *Annual report 2015-16.* ICAR- Central Marine Fisheries Research Institute, Kochi, India, 294 pp.

CMFRI 2016b. *Annual report 2016-17.* ICAR-Central Marine Fisheries Research Institute, Kochi, India, 344 pp.

CMFRI 2018. *Annual report 2017-18.* ICAR-Central Marine Fisheries Research Institute, Kochi, India, 304 pp.

CMFRI 2019. *Annual report 2018-19.* ICAR-Central Marine Fisheries Research Institute, Kochi, India, 306 pp.

Cochran, W. G. 1952. The χ^2 test of goodness of fit. *Ann. Math. Stat.,* 25: 315-345.

Compagno, L. J. V. and Last, P. R. 1999. Rhinidae (=Rhynchobatidae). Wedgefishes. In: Carpenter, K. E. and Niem, V. (Eds), *FAO identification guide for fishery purposes. The Living Marine Resources of the Western Central Pacific.* Food and Agricultural Organisation of the United Nations, Rome, Italy, p. 1418-1422.

Cortes, E. 1997. A critical review of methods of studying fish feeding based on analysis of stomach contents: Application to elasmobranch fishes. *Can. J. Fish. and Aquat. Sci*., 54: 726-738. DOI:10.1139/cjfas-54-3-726.

Devadoss, P. and Batcha, H. 1995. Some observations on the rare bow-mouth guitarfish *Rhina ancylostoma*. *Mar. Fish. Infor. Serv. T&E Ser.,* 138: 10-11.

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., Carlson, J. K., Davidson, L. N. K., Fordham, S. V., Francis, M. P., Pollock, C. M., Simpfendorfer, C. A., Burgess, G. H., Carpenter, K. E., Compagno, L. J. V., Ebert, D. A., Gibson, C., Heupel, M. R., Livingstone, S. R., Sansciangco, J. C., Stevens, J. D., Valenti, S. and White, W. T. 2014. *Extinction risk and conservation of the world's sharks and rays*. eLife 3: e00590. doi: 10.7554/eLife.00590.

Froese, R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. *J. Appl. Ichthyol.*, 22: 241-253. https://doi.org/10.1111/j.1439-0426.2006.00805.x.

Henderson, A. C., McIlwain, J. L., Al-Oufi, H. S. and Al-Sheili, S. 2007. The Sultanate of Oman shark fishery: Species composition, seasonality and diversity. *Fish. Res*., 86: 159-168. DOI10.1016/j.fishres.2007.05.012.

Jabado, R. W. 2018. The fate of the most threatened order of elasmobranchs: Shark-like batoids (Rhinopristiformes) in the Arabian Sea and adjacent waters. *Fish. Res.*, 204: 448-457.

Kizhakudan, S. J., Zacharia, P. U., Thomas, S., Vivekanandan, E. and Muktha, M. 2015. Guidance on National Plan of Action for Sharks in India. *CMFRI Marine Fisheries Policy Series No. 2,* ICAR-Central Marine Fisheries Research Institute, Kochi, India, 104 pp.

Klimley, A. P. 1987. The determinants of sexual segregation in the scalloped hammerhead shark *Sphyrna lewini*. *Environ. Biol.* Fish., 18(1): 27-40. DOI:10.1007/BF00002325.

Kock, A., O'Riain, M. J., Mauff, K., Meyer, M., Kotze, D. and Griffiths, C. 2013. Residency, habitat use and sexual segregation of white sharks, *Carcharodon carcharias* in False Bay, South Africa. *PLoS One*, 8(1): e55048. https://doi: 10.1371/journal.pone.0055048.

Kyne, P. M., Rigby, C. L., Dharmadi and Jabado, R. W. 2019. *Rhina ancylostomus. The IUCN Red List of Threatened Species 2019*: e.T41848A124421912.https://dx.doi.org/10.2305/IUCN.UK.2019-2.RLTS.T41848A124421912.en. (Accessed 11 May 2020).

Last, P. R., White, W. T., de Carvalho, M. R., Seret, B., Stehmann M. F. W. and Naylor, G. J. P. 2016. *Rays of the world.* CSIRO Publishing, Comstock Publishing Associates, Clayton, Australia, 790 pp.

Le Cren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *J. Anim. Ecol.,* 20: 201-219. https://doi.org/10.2307/1540.

Michael, S. W. 1993. *Reef sharks and rays of the world. A guide to their identification, behavior and ecology.* Sea Challengers, Monterey, California, USA, 107 pp.

Mohanraj, G., Rajapackiam, S., Mohan, S., Batcha, H. and Gomathy, S. 2009. Status of elasmobranchs fishery in Chennai, India. *Asian Fish. Sci*., 22(2): 607-615. https://doi.org/10.33997/j.afs.2009.22.2.023.

Montgomery, D. C., Peck, E. A. and Vining, G. G. 2012. *Introduction to linear regression analysis*, 5th edn. Wiley Publication, New Jersey, USA.

Moore, A. B. M. 2017. Are guitarfishes the next sawfishes? Extinction risk and an urgent call for conservation action. *Endanger. Species Res.,* 34: 75-88. https://doi.org/10.3354/esr00830.

Mucientes, G. R., Queiroz, N., Sousa L. L., Tarroso P. and Sims D. W. 2009. Sexual segregation of pelagic sharks and the potential threat from fisheries. *Biol. Lett.*, 5: 156-159. doi: 10.1098/rsbl.2008.0761.

Nair, R. J., Zacharia, P. U., Kishore, T. G., Kumar, S. D., Dhaneesh, K. V., Suraj, K. S. and Kumar, G. S. 2013. Heavy landings of mobulids reported at Cochin Fisheries Harbour, Kerala. *Mar. Fish. Infor. Serv. T&E Ser.,*.218: 19-20.

Pinkas, L., Oliphant, M. S. and Iverson, I. L. K. 1971. Food habits of albacore, bluefin tuna and bonito in California waters. *Cal. Fish Game*, 152: 1-105.

Purushottama, G. B.,Thakurdas, Ramasubramanian, V., Gyanaranjan, D., Akhilesh, K. V., Ramkumar, S., Kizhakudan, S. J., Singh, V. V. and Zacharia, P. U. 2017. Reproductive biology and diet of grey sharpnose shark *Rhizoprionodon oligolinx* Springer, 1964 (Chondrichthyes: Carcharhinidae) from the north-eastern Arabian Sea. *Indian J. Fish*., 64(4): 9-20. https://doi: 10.21077/ijf.2017.64.4.63379-02.

Purushottama, G. B., Thakurdas, Tandel, S. S., Mhatre, V. D. and Singh, V. V. 2018. Records of rare elasmobranchs and their biological observation from the north-eastern Arabian Sea, off Mumbai. *Indian J. Mar. Sci.,* 47(8): 1566-1573.

Purushottama, G. B., Ramasubramanian, V., Akhilesh, K. V., Raje, S. G., Thakurdas, Kizhakudan, S. J. and Zacharia, P. U. 2020. Biological observations on the Bengal guitarfish *Rhinobatos annandalei* Norman, 1926 from the Eastern Arabian Sea, India, *Indian J. Fish.,* 67(2): 23-34. https://doi: 10.21077/ijf.2019.67.2.94482-04.

Raje, S. G. 2006. Skate fishery and some biological aspects of five species of skates off Mumbai. *Indian J. Fish.*, 53(4): 431-439.

Raje, S. G., Sivakami, S., Mohan Raj, G., Manoj Kumar, P. P., Raju, A. A. and Joshi, K. K. 2007. *An atlas on the elasmobranch fishery resources of India. Special Publication No. 95,* ICAR-Central Marine Fisheries Research Institute, Kochi, India, 253 pp.

Roy, B. J., Ali, S. M. H., Singha, N. K. and Rhaman, M. G. 2013. Sharks and rays fisheries of the Bay of Bengal at the landing centers of Chittagong and Cox's Bazar, Bangladesh. *Bangladesh J. Zool.,* 41(1): 49-60. DOI: https://doi.org/10.3329/bjz.v41i1.23298.

Roy, B. J., Alam, M. F., Rhaman, M. G., Singha, N. K. and Akhtar, A. 2014. Landing trends, species composition and percentage contribution of sharks and rays in Chittagong and Cox's Bazar, Bangladesh. *Global Journal of Science Frontier Research: (D) Agriculture and Veterinary,* 14(1) Ver. 1: 16-26. Online ISSN: 2249-4626 and Print ISSN: 0975-5896.

Shapiro, S. S. and Wilk, M. B. 1965. An analysis of variance test for normality (complete samples), *Biometrika,* 52(3&4): 591-611. https://doi.org/10.2307/2333709.

Si, R., Chena, H., Ai, W., Chen, X. and Chen, S. 2016. Complete mitochondrial genome and the phylogenetic position of the Bowmouth guitarfish *Rhina ancylostoma* (Rajiformes, Rhinobatidae). *Mitochondrial DNA Part B*, 1(1): 270-272. https://doi: 10.1080/23802359.2016.1159935.

Sims, D. W. 2005. Differences in habitat selection and reproductive strategies of male and female sharks. In: Ruckstuhl, K. E. and Neuhaus, P. (Eds.), *Sexual segregation in vertebrates: Ecology of the two sexes*. Cambridge University Press, Cambridge, UK, p. 127-147.

Springer, S. 1967. Social organisation of shark populations. In: Gilbert, P. W., Mathewson, R. F. and Rall, D. P. (Eds.), *Sharks, skates and rays*. John Hopkins University Press, Baltimore, USA, p. 149-174.

Stehmann, M. F. W. 2002. Proposal of a maturity stages scale for oviparous and viviparous cartilaginous fishes (Pisces, Chondrichthyes). *Arch. Fish. Mar. Res*., 50: 23-48.

Steven, G. A. 1933. Rays and skates of Devon and Cornwall, III. The proportions of the sexes in nature and in commercial landings and their significance to the fishery. *J. Mar. Biol. Ass. UK.,* 18: 611-625.

Stevens, J. D. and Mcloughlin, K. J. 1991. Distribution, size and sex composition, reproductive biology and diet of sharks from northern Australia. *Aust. J. Mar. Freshw. Res.,* 42: 151-199. https://doi.org/10.1071/MF9910151.

Stevens, J. D., Bonfil, R., Dulvy N. K. and Walker, P. A. 2000. The effects of fishing on sharks, rays and chimaeras (Chondrichthyans) and the implications for marine ecosystems. *ICES J. Mar. Sci.*, 57: 476-494. https://doi.org/10.1006/jmsc.2000.0724.

Stobutzki, I. C., Miller, M. J., Heales, D. S. and Brewer, D. T. 2002. Sustainability of elasmobranchs caught as bycatch in a tropical prawn (shrimp) trawl fishery. *Fish. Bull.,* 100: 800-821.

Tuntivanich, N. and Cheunsuang, O. 2017. Preliminary investigation of the ocular macroscopic structure of a bowmouth guitarfish (*Rhina ancylostoma* Bloch and Schneider 1801). *J. Anim. Health Behav. Sci*., 1: 1-2.

Venkateswaralu, T. 1967. *Rhina ancylostoma* Schneider from the in-shore waters off Portonovo, S. India. *J. Bombay Nat. Hist. Soc.,* 64: 118-119.

Vidthayanon, C. 2005 *Thailand red data: Fishes.* Office of Natural Resources and Environmental Policy and Planning, Bangkok, Thailand, 108 pp.

Walker, T. I. 1998. Can shark resources be harvested sustainably? A question revisited with a review of shark fisheries. *Mar. Freshw. Res.,* 49: 553-572. https://doi.org/10.1071/MF98017.

Wearmouth, V. J. and Sims, D. W. 2010. Sexual segregation in elasmobranchs. *Biol. Mar. Mediterr.,* 17(1): 236-239.

White, W. T. and Dharmadi 2007. Species and size composition and reproductive biology of rays (Chondrichthyes, Batoidea) caught in target and non-target fisheries in eastern Indonesia. *J. Fish Biol.,* 70: 1809-1837. https://doi:10.1111/j/1095-8649.2007.01458.x.

White, W. T. 2007. Catch composition and reproductive biology of whaler sharks (Carcharhiniformes: Carcharhinidae) caught by fisheries in Indonesia. *J. Fish Biol.,* 71(5): 1512-1540. https://doi:10.1111/j/1095-8649.2007.01623.x.

Wood, M. 2004. Statistical inference using bootstrap confidence intervals. *Significance,*1: 180-182. https://doi.org/10.1111/j.1740-9713.2004.00067.x.

Date of Receipt : 16.11.2021

Date of Acceptance : 12.07.2022