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Biological observations on the Bengal guitarfish *Rhinobatos annandalei* Norman, 1926 from the Eastern Arabian Sea, India

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ABSTRACT

Biological data for the little known Bengal guitarfish *Rhinobatos annandalei* Norman, 1926 (Rhinopristiformes: Rhinobatidae) are presented based on specimens collected from bycatch of commercial shrimp trawlers, gill netters and bag or dol netters operating in the Arabian Sea at depths of 2-70 m off the north-west coast of India. Five hundred ninety three specimens measuring 30.0 to 95.0 cm total length (TL) and weighing between 64.0 to 3300 g total weight (TW) were collected for the study. The length-weight relationships (LWR) were significantly different between the sexes ($p<0.001$) and the LWR for the combined sexes was derived as $TW= 0.000604\ TL^{3.408256}$ ($r^2= 0.997$). The co-efficients 'a' and 'b' of the LWR were estimated as 0.000621, 3.410115 ($r^2= 0.999$) for females and 0.000766, 3.333872 ($r^2= 0.999$) for males. The length at maturity (TL_{50}) for females and males was estimated to be 61.0 and 63.3 cm TL, respectively. In a single female, the number of embryos ranged from 2 to 11 and the size at birth was estimated between 25.0 to 30.0 cm TL. The overall sex ratio favoured females at the rate of 1.6:1. An analysis of the stomach contents (%IRI) revealed that *R. annandalei* mainly fed on *Solenocera* spp. (18.7% IRI), along with *P. sculptilis* (0.5% IRI), *P. stylifera* (0.4% IRI), *Loligo* spp. (0.4% IRI) and sciaenids (0.3% IRI). Since, the species is poorly studied and assessed as 'Data Deficient' in the IUCN red list criterion, it is anticipated that the biological results from the present study, will update information on the species thereby enabling more effective management decisions.

Keywords: Arabian Sea, Diet, Length at maturity, Length-weight relationship, Reproductive biology, *Rhinobatos annandalei*

Introduction

Shovelnose rays (guitarfishes) of the family Rhinobatidae (Rhinopristiformes) represented worldwide by 3 genera and about 31 species, is most diverse in the Indo-West Pacific (Last *et al*., 2016). All the batoids, especially Rhinopristiformes are considered to be at high risk of extinction in certain parts of the world and in view of this, a proposal to include all of them in the CITES annex is in the process (Moore, 2017). The Bengal guitarfish, *Rhinobatos annandalei* Norman, 1926, currently has a distribution range from Sri Lanka, India, Pakistan and also possibly from the Gulf (Last *et al*., 2016; Jabado, 2018). It is classed in the IUCN red list threatened species as data deficient (DD) (Valenti, 2009). Raje (2006) reported that *R. annandalei* is caught as bycatch in shrimp trawls, the landing of which had increased from nil during 1989-1993 to 0.26 t in 1994-1998 and later to 7.56 t in 1999-2003. However, the average annual landings decreased to 1.8 t during 2012-2016 (CMFRI, 2013; 2014; 2015; 2016). Though forming a fishery component in its distribution range, knowledge of its life history is poor and limited to a few studies in the north-eastern Arabian Sea (Vossoughi and Vosoughi, 1999; Raje, 2006; Raje *et al*., 2012; Jabado, 2018). Further, most of these studies are restricted to either length frequency or length-weight relationships and do not elicit details regarding its reproductive biology or diet. Therefore, understanding the species composition of landings and the biological traits of exploited shark-like batoids is crucial for the development and implementation of effective management and conservation strategies for them in Indian waters.

Elasmobranch fisheries demand vigilant management strategies that support sustainable and continuous harvest, while ensuring that the resource is not overexploited and avoids adverse impact on the ecosystem and extinction risk (Moore *et al*., 2012; Jabado *et al*., 2017; Jabado, 2018; Jabado *et al*., 2018). Guitarfishes have been identified as being amongst the most vulnerable of the elasmobranch families, after sawfishes (Dulvy *et al*., 2014; Moore, 2017). Its vulnerability is further compounded by limited information on its reproductive biology, diet and stock assessment in the northern Indian

Ocean. For this reason, the present study aims to perceive the reproduction, maturity, length-weight relationship and diet characteristics of *R. annandalei* caught along the north-west coast of India, in the northern Indian Ocean and to provide detailed information on its life history traits.

Materials and methods

A total of 593 specimens of *R. annandalei* were collected from the bycatch landings of commercial shrimp trawlers, gillnetters and bag or *dol* netters operating in the northern Arabian Sea during 2012-2016 at 2-70 m depth and landed at the New Ferry Wharf (18° 57' 28.85'' N; 72° 51' 02.73'' E), Sassoon Docks (18° 54' 42.43'' N; 72° 49' 33.16'' E), Satpati (19° 43' 30.75'' N; 72° 42' 08.30'' E and at Alibaug (18° 38' 4.25'' N; 72° 52' 38.95'' E) fishing harbours along Maharashtra coast (Fig. 1).

The total length (TL) of each specimen was measured to the nearest mm and the total body weight (TW) to the nearest g and after recording the sex, the specimens were categorised based on TL and umbilical scar. The umbilical scar was assessed based on the healing stage (*e.g.* open, healing, or closed). The opened and healing umbilical scars characterise the neonate period, while the closed scars denote juveniles. The weekly length frequency data of *R. annandalei* collected were raised to the monthly and annual figures using the Stratified Random Sampling technique (Alagaraja, 1984).

The length-frequency distribution was tested for normality using the Shapiro-Wilk test. As the data followed normal distribution, size differences between females and males were tested using the two-tailed *t* -test. This was to ascertain any sex-based differences in landings. The size-frequency distribution of females and males was compared using the χ^2 test with the size distribution divided into 5.0 cm class intervals of TL (Cochran, 1952). To test sex ratios being at parity, the two sided exact ratio test was employed (Biradar, 2002). The seasonal sex ratio was estimated considering three seasons, namely, pre-monsoon (February-May), monsoon (June-September) and post-monsoon (October-January).

The sex and maturity stages were examined using the maturity scale proposed by Stehmann (2002), based on the ovarian and uterine condition for females and clasper calcification for males. For calculation of length at maturity (TL_{50}) for females and males, the specimens were classed as either immature (uncalcified or partially calcified claspers for males and ovaries not developed or with maturing oocytes, but uteri thin and ribbon-like for females) or mature (claspers fully calcified; ovaries and uteri both fully developed). For males, the outer clasper length (OCL) was recorded to establish clasper length *vs.* size relationship.

The TL_{50} for females and males was derived from the following logistic regression, where the proportion (pL), of guitar fishes that were mature at TL was calculated as: $pL = \{1 + e^{[-\ln (19)(TL - TL_{50})(TL_{95} - TL_{50})]^{-1}}\}^{-1}$, where TL_{50} and TL_{95} are constants and ln is the natural logarithm (Wood, 2004; White, 2007, Purushottama *et al.,* 2017). Maximum likelihood estimates of the parameters were obtained using the routine SOLVER in Microsoft™ Excel and by calculating the likelihood of immature and mature individuals as 1-pL and pL, respectively. The

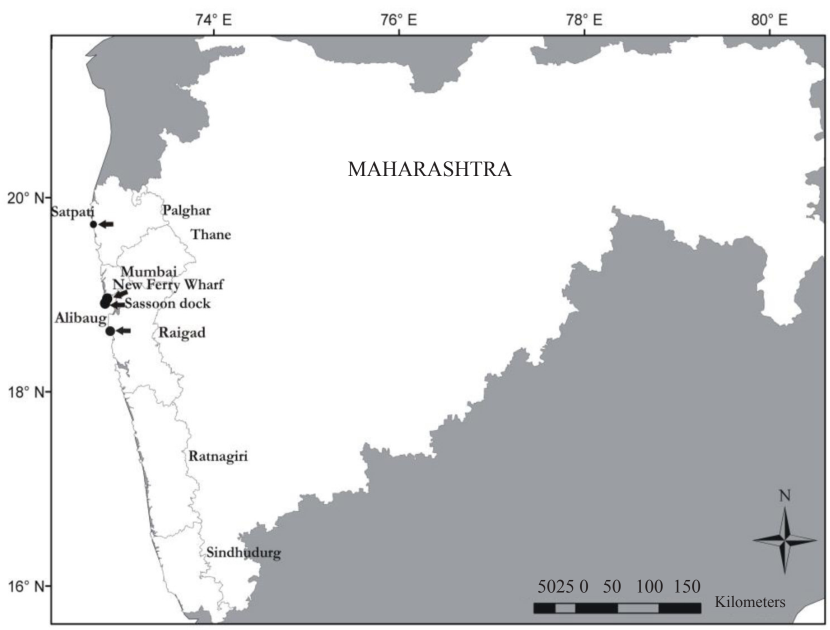

Fig. 1. Map showing *R. annandalei* sampling sites

reported estimates of the parameters were determined as the median values derived from 200 sets of randomly re-sampled data, with the same sample size, drawn from the data on the observed maturity status at TL for female and male guitarfishes. The c. 95% C. I. was estimated as 2.5 and 97.5 percentiles of the 200 estimates resulting from these re-sampled data.

The parameters '*a'* and '*b'* of the length-weight relationships (LWR) were estimated using the equation proposed by Le Cren (1951): $TW= a *TL^b$. After logarithmic transformation of the length and weight data, this equation may be expressed as: $\log TW= \log a+ b* \log TL$; where, TW is the weight of the fish in g and TL is the total length of the fish in cm, *a* is the intercept of the regression curve (coefficient related to body form) and *b* is the regression coefficient (exponent indicating isometric growth; Froese, 2006). The confidence and prediction intervals were calculated for the length and weight of the guitarfish in the LWRs using the following formulae: the confidence interval for the mean response when predictor is x* is $\hat{y} \pm t^*S\epsilon \sqrt{1/n+(x^*-x)^2/(n-1)s^2_x}$ and the prediction interval for an individual response when the predictor is x* is $\hat{y} \pm t^*S\epsilon \sqrt{1+1/n+(x^*-x)^2/(n-1)s^2_x}$ (Montgomery *et al*., 2012). The male and female LWR was tested for significant difference using the extra sum of squares method involving full and reduced regression models for testing the common slope (parallel lines), while the *F*-statistic was computed to test the difference between the two slopes (Montgomery *et al*., 2012).

Equations for the relationship between size and weight were obtained by fitting a power curve of the form $y=ax^b$ using Microsoft™ Excel. For those species for which an equation for the relationship between size and weight was calculated, the weight of each individual measured but not weighed was calculated using the above equation for that particular species. For each species, the weight of those individuals recorded but without a size measurement were estimated by obtaining an average weight of individuals for that species using the above methodology. Total weight was then determined for each batoid species.

To describe the diet, percent frequency of occurrence (%*O*), percent composition by number (%*N*) and percent composition of weight (%*W*) was used to estimate the percent index of relative importance (%IRI) as IRI=(%N +%W)* %O (Pinkas *et al.,* 1971). The IRI was expressed as %IRI to allow for a comparison of the values between the prey groups (Cortes, 1997).

Results

Species composition of Rhinopristiformes

Families Rhinidae, Rhinobatidae and Pristidae were observed at the fish landing centres visited in Maharashtra as eight taxonomically defined species and one *Rhynchobatus* sp., which contributed 41.1% to the total biomass of the batoidea (Table 1). *R. annandalei* contributed only 3.5% to the total biomass of all batoidea. The present investigation was not only limited to biological studies, but also quantitative assessment of the resources was undertaken to ascertain the landings in Maharashtra on the north-west coast of India. However, it was observed that Bengal guitarfish constituted about 2% of the total catch of batoidea landings in Maharashtra region. The estimated annual landings (2012-2016) of *R. annandalei* by shrimp trawlers, gillnetters and bag or *dol* netters together as bycatch was higher in 2016 (3.1 t) and 2015 (3.0 t), but much lower in the three previous years, *i.e.* 0.1 t in 2012, 0.2 t in 2014 and 0.6 t in 2013. Thus, there was 40 times increase in landings in 2016 compared with 2012.

Table 1. Percentage contribution by biomass (%B) and minimum and maximum total length (TL) of each species of shark-like batoids recorded at fish landing centres in eastern Arabian Sea

Species	Common name	%B	TL (cm)	
			Minimum	Maximum
Shark-like batoids		41.1		
Rhinobatos annandalei	Bengal guitarfish	3.5	30.0	95.0
Rhina ancylostoma	Bow mouth guitarfish	16.6	28.0	231
Rhynchobatus spp.	Wedge fishes	41.4	44.0	290
Rhynchobatus australiae	Bottlenose Wedge fish	14.0	55.0	235
Rhynchobatus laevis	Smoothnose Wedge fish	15.0	58.0	259
Glaucostegus granulatus	Granulated guitarfish	0.6	58.0	154
Glaucostegus halavi	Halavi guitarfish	0.1	NA_{min}	65.0
Glaucostegus obtusus	Grey guitarfish	1.0	26.5	101
Pristis pristis	Large tooth sawfish	7.8	NA_{min}	400
Total (of all batoidea recorded)		37387 kg		

NA_{min}: Minimum size not available

Sex and size distribution

Commercial shrimp and fish trawlers, gillnetters and bag or *dol* netters land Bengal guitarfish as bycatch along Mumbai, Palghar and Raigad in Maharashtra region throughout the year, except during the south-west monsoon due to rough weather and uniform mechanised fishing ban by the Government of India on the west coast from June 01 to July 31. The number of sampled specimens ranged from 14 in December 2012 to 195 in September 2016 (Pooled data).

Overall 593 specimens of 30.0-95.0 cm TL (mean±SD =56±18 cm) and weighing between 68.0 to 3300 g (mean±SD=805±705 g) in case of females and of 30.0 to 95.0 cm TL (mean±SD=48±15 cm) and weighing between 64.0 to 2961 g (mean±SD=435±364 g) in case of males were observed to attain similar maximum size.

The monthly length frequency distribution (pooled years) did not present clear trends for females and males (Fig. 2a-j). The landings were represented by a wide size range of specimens in all the months for which the data was obtained. Of these, fourteen size classes (5.0 cm TL intervals) were used for length classification, from 30.0 to 95.0 cm TL (Fig. 3). The χ^2 test revealed significant difference ($p<0.001$) in length frequency distribution with more females caught in the size class 65.0-85.0 cm TL and most males caught in the size class 50.0-75.0 cm TL.

The overall sex ratio (F:M) in the landings was 1.6:1 in favour of females, which significantly deviated from the expected ratio of 1:1 ($p<0.05$). The seasonal sex ratio was estimated considering three seasons. The pre-monsoon (February-May) sex ratio was 0.8:1, for monsoon (June-September) it was 2.8:1 and in post-monsoon (October-January) it showed 1.4:1. The distribution of females and males of *R. annandalei* was significantly different in the sampling months (χ^2, d.f. = 9; $p<0.001$).

The distribution of the number of females and males differed significantly in the different sub-groups *viz.,* juveniles, sub-adults and adults (χ^2, d.f. = 2, $p<0.001$). The sex ratio of female to male in juveniles (<50 cm TL), sub-adults (51-63 cm TL) and adults (>63 cm TL) was 0.97:1, 0.62:1 and 4.1:1, respectively.

The distribution pattern of *R. annandalei* (females and males) juveniles, sub-adults and adults in different months (pooled data) showed that juveniles (<50 cm TL) were observed maximum in January (19%), March (18%) and May (17%); sub-adults (51-60 cm TL) in August (30%) and September (28%) and adults (>61 cm TL) accounted for maximum in September (58%) and August (24%) for female (Fig. 4a). In the case of males, juveniles (<50 cm TL) appeared in January-May and peaked in February (20%), sub-adults (51-62 cm TL) in August (22%) and September (32%) and adults (>63 cm TL) between September and August with the highest in September (44%) (Fig. 4b).

Length-weight relationships

The weight of *R. annandalei* ranged between 68.0 to 3300 g in females and between 64.0 to 2961 g in males. The equations relating to total length (TL) and weight (TW) (TL *v.* TW) consisting of 251 females (30.0 -95.0 cm TL) and 183 males (30.0-95.0 cm TL) are presented below, thus enabling an approximate weight of the Bengal guitarfish to be estimated from a given total length (Fig. 5a, b, c). The slopes were found to be significantly different between the sexes ($p<0.001$).

Females: $MT = 0.000621\ TL^{3.410115}$ (r^2= 999, 95% C.I. of b= 3.239609 -3.580621, n=251)

Males: $MT = 0.000766\ TL^{3.333872}$ (r^2= 0.999, 95% C.I. of b= 3.167178-3.500566, n=183)

There was significant difference between the length and weight relationship of the females and males (*t*-test, d.f. =591, $p<0.001$). For females and males, the average length and weight were significantly different in all the sampling months (χ^2, d. f. =9, $p<0.001$).

Reproductive biology

A total of 593 (females = 367; males =226) samples were used for the reproductive biology studies. Mature females, with ovaries containing maturing oocytes (maximal ovarian fecundity) ranged from one to eleven (mean±SD=8.0±2.7) and oocyte diameter measuring 5.1 mm to 39 mm (mean±SD =21.1±7.5). Functional uteri, were observed in specimens of 65.0 to 95.0 cm TL. The largest immature female measured 74 cm in TL. The female *R. annandalei* matured between 60 and 65 cm, with 50% maturity occurring at 61.0 cm TL (95% C.I) (Fig. 6a). The smallest mature male *R. annandalei* recorded was of 61 cm TL and the largest immature male was 65 cm in TL. The males matured in different size range (60-65 cm) and 50% maturity occurred at 63.3 cm TL (95% C.I.) (Fig. 6b).

The claspers of male *R. annandalei* are elongated and rigid at approximately 55 cm TL and most of the examined samples were fully calcified at >60 cm TL. Sizes of maturity classes for *R. annandalei* were <50 cm TL (28.3%, n=104) for juveniles, between 51-60 cm TL (10.9%, n=40) for sub-adults and >61 cm TL for mature

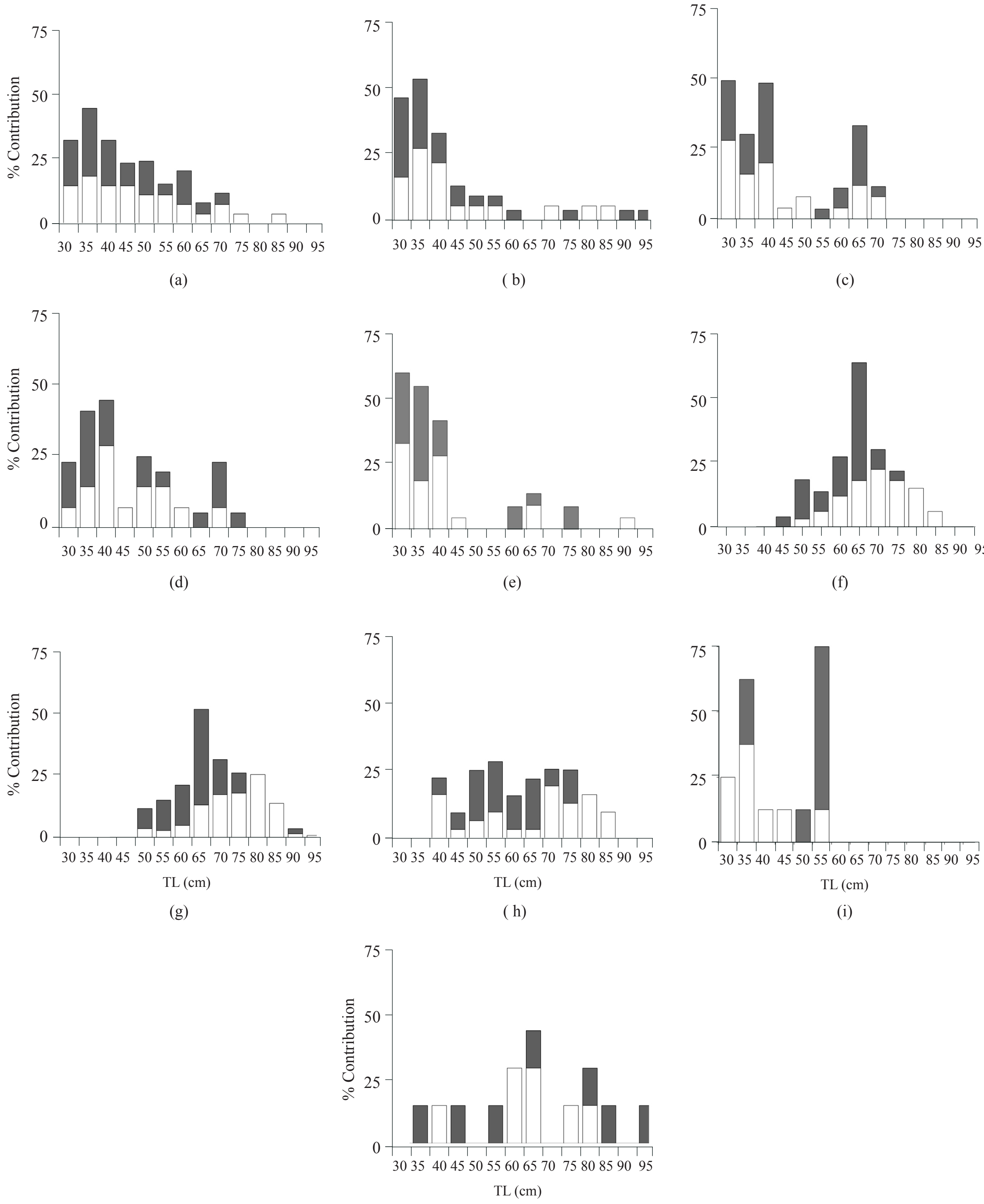

Fig. 2. Monthly total length (TL)-frequency histograms for females (□) and males (■) of *R. annandalei* from Maharashtra between January 2012 to December 2016. Data pooled over the five years for (a) January, (b) February, (c) March, (d) April, (e) May, (f) August, (g) September, (h) October, (i) November, (j) December

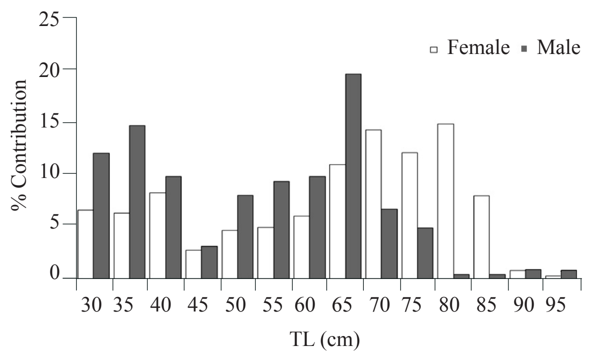

Fig. 3. Total length (TL)-frequency histogram of *R. annandalei.* Females (□) *n* = 367; Males (■) *n* =226

adult (60.8%, *n*=223) in case of females and <50 cm TL (47.3%, *n*=107) for juveniles, between 51-62 cm TL for sub-adults (28.8%, *n*=65) and >63 cm TL for mature adult (23.9%, *n*=54) of males. The classification was done based on 50% maturity (TL_{50}).

One hundred eight pregnant females of *R. annandalei* (68.0-84.2 cm TL; mean±SD=72.6±3.6 cm) were dissected and it was found that each contained two to eleven (mean±SD=2.3±1.2) fully formed embryos of 25.0-30 cm TL (mean±SD=25.5±3.2 cm), weighing between 50.0 to 58.0 g (mean±SD=53±3.5 g). The reproductive mode was aplacental viviparity. The size-frequency distribution of pregnant *R. annandalei* is presented in Fig. 7. The pregnant females were observed in all months and exhibited a non-seasonal reproductive cycle. Maximum pregnant females were observed in the length classes of 66.0 -70.0 cm TL, 71.0-75.0 cm TL, 76.0-80.0 cm TL and 81.0 -85.0 cm TL (Fig. 8). Near-term embryos, ranging in size from 20.0-25.0 cm TL, had a yolk-sac stalk still attached and the late term (near to parturition) embryos of 25.0-30.0 cm TL were found to have an umbilical scar. The smallest specimen observed in the fishery was 30 cm TL, however, the number of newborn/juveniles observed in the gillnet catch was very low (in the *dol* or bag netter and trawler landings at Maharashtra, a number of newborns of 30.0-35.0 cm TL were observed). Based on the current dataset, the size at birth of *R. annandalei* in the north-west coast of India was estimated to range from 25.0 to 30.0 cm TL. The greatest number of embryos *i.e.*, 12 (left 6 and right 6) of mean size 10.6 cm TL and sex ratio of 0.8:1 (female: male) was recorded for *R. annandalei* of 82.5 cm TL and weighing 2000 g. The overall sex ratio within the embryos in the 201 litters (from 108 females) studied was not significantly different from parity (d.f. =1, $p>0.05$) and the sex ratio of the embryos was observed to be 1.2:1 (female to male), with the largest embryos observed being of 30.0 cm TL in case of females and 29.5 cm TL for males. The OCL of the smallest male was 1.9 cm (specimen of 30.0 cm TL), while that of the largest was 11.3 cm (specimen of 95.0 cm TL) and there was noticeable increase in OCL with TL (Fig. 9).

Feeding habit

A total of 357 specimens (40.0-95.0 cm TL) were examined for understanding the prey selection of *R. annandalei*. Of these, only 30% (*n*=107) contained prey items and were analysed for the index of relative importance (IRI), 26.0% (*n*=92) contained either semi-digested or highly digested and trace food that could not be identified and 44.0% (*n*=157) were empty. The fullness of the stomach revealed that 4.5% (*n*=16) were a quarter full, 15.7% (*n*=56) were a half full, 30.3%

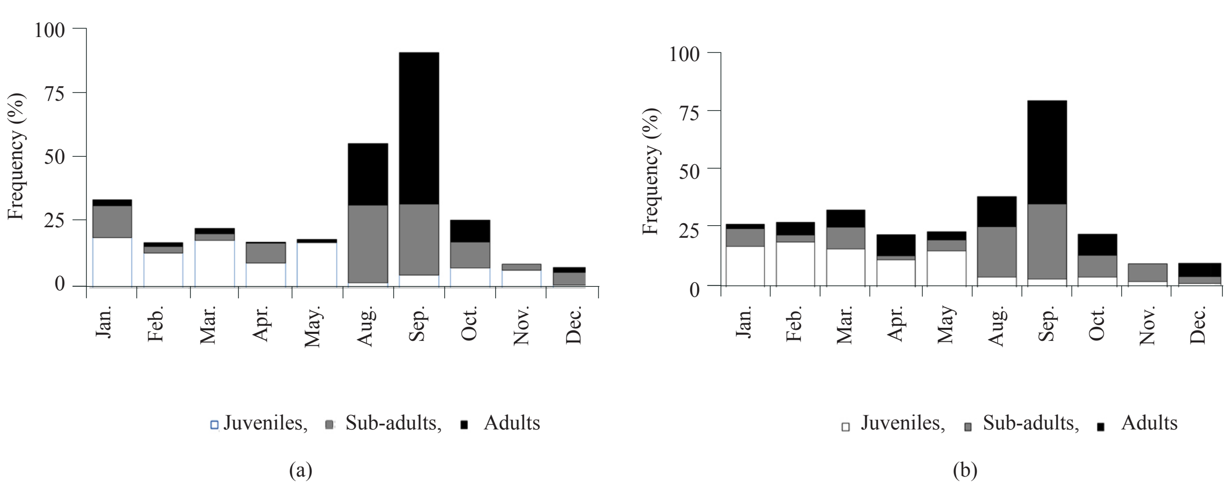

Fig. 4. Monthly frequency of occurrence of *R. annandalei* sampled from Maharashtra between January 2012 to December 2016 (Pooled data) for (a) female and (b) male

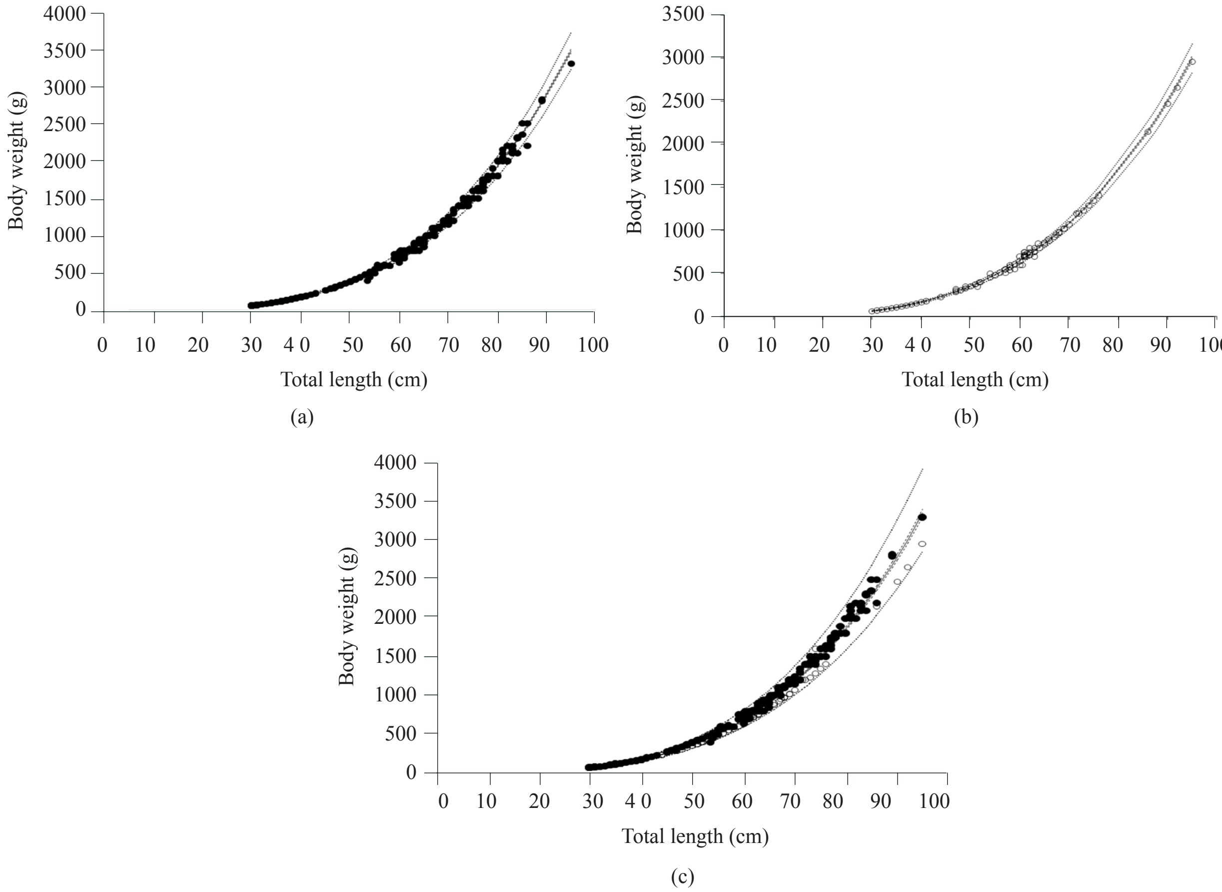

Fig. 5. Length-weight (TL-TW) relationship of *R. annandalei* for (a) female (b) male and (c) combined sex. Plots are mean body weight at length (–) with 95% confidence intervals (---), 95% prediction intervals (…) and raw data – females (•) and males (°)

(*n*=108) contained trace contents only and 5.6% (*n*=12) were full. The prey items were recognised in females and males of length range 70.0 cm-95.0 cm TL (*n*=107) and were analysed for IRI. Analysis of the stomach contents (%IRI) revealed that *R. annandalei* fed primarily on crustaceans (66.5%), teleosts (33.1%) and cephalopods (0.4%). The major prey items included *Solenocera* spp. (%IRI=18.7), *Parapenaeopsis sculptilis* (%IRI=0.5), *Parapenaeopsis stylifera* (%IRI =0.4) and sciaenids (%IRI=0.4) (Table 2).

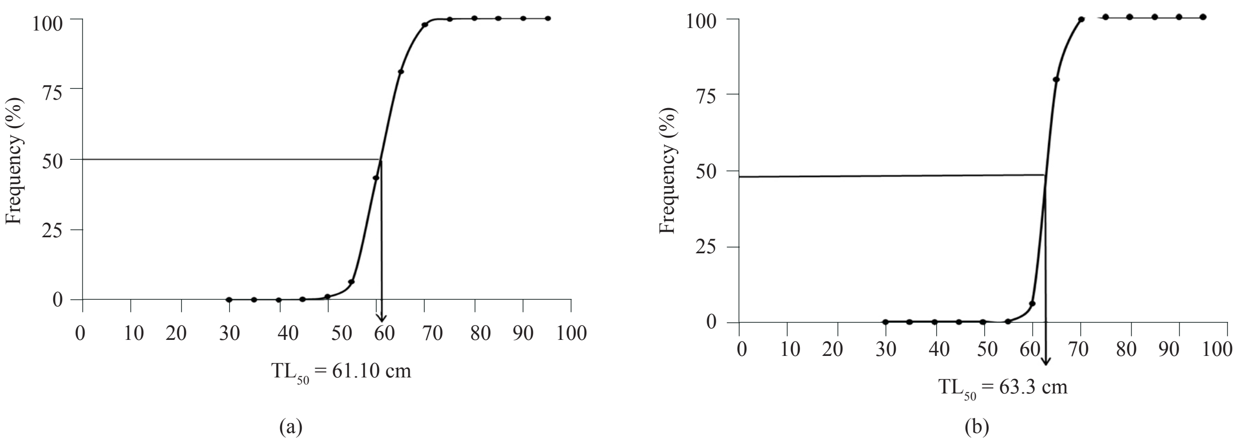

Fig. 6. Length at maturity of *R. annandalei* (a) female and (b) male. Arrows indicate the TL at which 50% of females and males attain maturity (TL_{50}).

Discussion

The present study provides essential information on the reproductive biology, length at maturity, length-weight relationship and diet of the sparsely studied Bengal guitarfish, *R. annandalei* found in the northern Indian Ocean. A continuous survey of the biodiversity, biology and fisheries of the north-eastern Arabian Sea elasmobranchs provided new information on the shark-like batoid fauna of the region. The nine shark-like batoid species recorded in this study are classified in the IUCN Red List as Data Deficient, Vulnerable and Critically Endangered or Not Evaluated due to lack of taxonomic clarification and are therefore, not evaluated (IUCN, 2018). *Rhinobatos annandalei* was often misidentified as *Rhinobatos punctifer* in the Arabian Sea and adjacent waters for a long time until Last *et al.* (2016) and Jabado (2018) drew attention to the fact. *R. punctifer* was described by Compagno and Randall (1987) as being found in the Gulf of Aqaba in the northern Red Sea. By and large, *R. annandalei* can be observed in both the east and west coasts of India (Talwar and Kacker, 1991).

Though *R. annandalei* is common in the fishery along the southern and eastern coast of India, its documentation is limited and mostly unreported from many regions. Species-specific life history traits are essential for making any assessment or management recommendations. The size range of *R. annandalei* observed in the trawl/gill net/bag or *dol* net fishery of the northern Arabian Sea (30.0-95.0 cm TL) differed from those reported from other regions. Vossoughi and Vosoughi (1999) recorded a single specimen in the Persian Gulf and the Sea of Oman. Jabado (2018) examined 42 specimens of both sexes (40.4-86.5 cm TL) in the UAE and Oman. Raje (2006) and Raje *et al*. (2007) observed 452 individuals measuring upto 85.0 cm TL, while Raje *et al*. (2012) studied 365 specimens (27.0-85.0 cm TL for females and 30.0-74.0 cm TL for males) and Gladston *et al*. (2018) examined 13 specimens (34.0-65.0 cm TL for females and 46.0-89.0 cm TL for males) in Mumbai waters. Furthermore, the present study has recorded the longest TL for *R. annandalei* (95.0 cm TL) to date. These differences could be the result of several factors like fishing gear selectivity and/or sample size and regional differential growth based on habitat (Motta *et al.,* 2005). The difference detected between size-frequency distribution of females and males is probably a consequence of sexual segregation, a general characteristic of elasmobranchs that is normally associated with reproduction, sex-specific migration into inshore waters or competition and season (Ford, 1921; Steven, 1933; Springer, 1967; Klimley, 1987; Stevens and Mcloughlin, 1991; Motta *et al*., 2005; Mucientes *et al.,* 2009; Wearmouth and Sims, 2010).

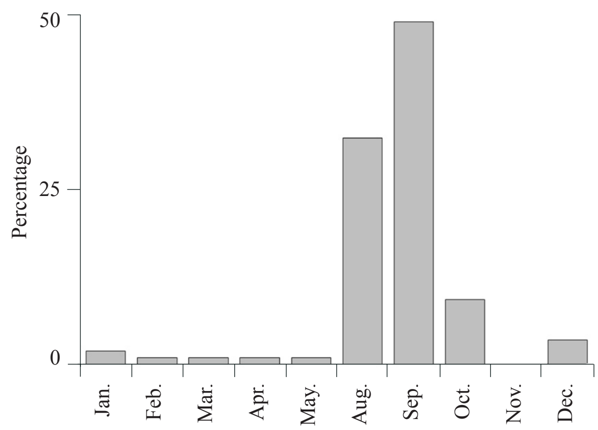

Fig. 7. Percent frequency of occurrence of pregnant females of *R. annandalei*

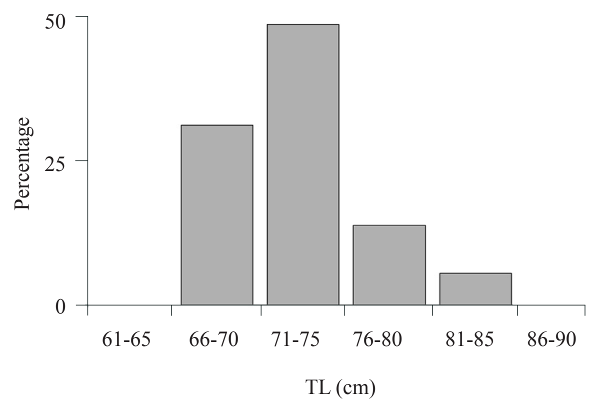

Fig. 8. Total length (TL)-frequency histogram of pregnant *R. annandalei*

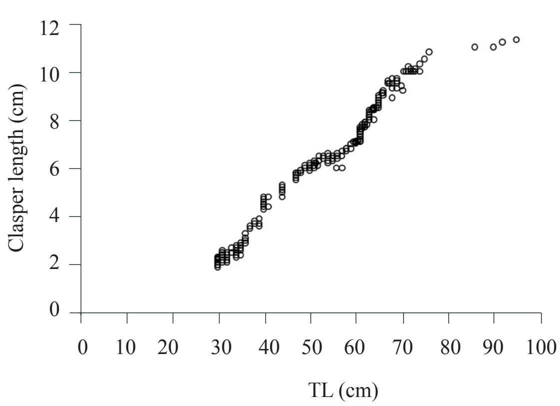

Fig. 9. Relationship between outer clasper length (OCL) and total length of males of *R. annandalei*

There is no published information available on biology of *R. annandalei* and much of the batoid literature in the region is a decade old (Raje, 2006; Raje *et al*., 2007). The overall sex ratio of females to males recorded from the landings (1.6:1), showed sexual segregation in this species in the north-eastern Arabian Sea and unequal trends in monthly sex ratios. The seasonal and size-class sex ratio analyses indicated that the juveniles, sub-adults and adults of *R. annandalei* showed sex and size segregation. However, observations by Raje (2006) indicated that females and males were unequally distributed in the fishery during 1989-2003 and the sex ratio to be 1.2:1. Raje *et al.* (2012) made a similar observation regarding female to male ratio as 1.2:1 based on 365 specimens for 1999-2005 from Mumbai. White and Dharmadi (2007) analysed the sex ratio of 6 of the 54 species of batoids, which differed significantly from parity in eastern Indonesia and more females were observed in the sampling of *Rhynchobatus australiae*, *Dasyatis* cf. *kuhlii* (Java form), *Gymnura poecilura*, *Dasyatis zugei*, *Himantura jenkinsii* and *Pteroplatytrygon violacea*. Similarily, *Rhinobatos jimbaranensis* showed skewed sex ratio (1.4:1) with female dominance in the landings, whereas *Rhinobatos penggali* showed sex ratio of 0.97:1. Jabado (2018) recorded female to male ratio as 1.1:1 based on 42 specimens of *R. annandalei* for 2010-2012 from the Arabian Sea and adjacent waters. In the same genera, Farrugia *et al*. (2011) recorded abundance, habitat use and movement patterns of *Rhiobatos productus* in a restored southern California estuary and found no evidence of sexual segregation by season based on the sex ratio of the catch. Unequal sex ratios can be the result of sexual segregation by depth or area and/or gear selectivity (Akhilesh *et al*., 2013).

In the present study, the length-weight relationship (TL *vs.*TW) of *R. annandalei* was significantly different between the sexes. Raje *et al*. (2007) estimated co-efficients '*a*', and '*b*' of the length-weight relationship as -4.3293 and 2.9568 (r= 0.91, *n*=179) for females and -3.6020 and 2.3234 (r= 0.8, *n*=85) for males. Gladston *et al*. (2018) reported length-weight relationship (combined sexes) as $W = 0.0012*L^{3.2099}$ (r^2= 0.9871, *n*=13). Co-efficients '*a*' and '*b*' of the length-weight relationship were estimated to be 0.0034 and 3.1946 (r^2= 0.9991, *n*=5) for females and 0.0014 and 3.1795 (r^2= 0.9740, *n*=8) for males in the north-eastern Arabian Sea. On the contrary, the observations of the present study indicated that females and males followed allometric growth b>3 (the fish grows faster in weight than in length) in the same study area. According to Stevens and Wiley (1986), these variations between length–weight relationships of females and males could be a result of different sample sizes, unequal distribution of sizes within each dataset of each sex or even of non-pregnant females being lighter due to inclusion of spent fish, which have a lower condition factor.

The TL_{50} of females at maturity determined in the present study was 61.9 (60-65) cm TL for *R. annandalei*. Information on the length at maturity for females of *R. annandalei* is limited. However, the observation made by Raje (2006) indicated that mature females observed during 1989-2003 period was 60 cm TL, while Raje *et al.* (2012) on studying the breeding behaviour of elasmobranchs in Mumbai waters, recorded the lowest length of a mature female *R. annandalei* to be 59.0 cm TL.

There is paucity of data on length at maturity of male *R. annandalei*, as smallest adult male observed in the present study was 61 cm TL, while the smallest adult male observed by Raje (2006) and Raje *et al*. (2012) was 50 cm TL. The TL_{50} of males at maturity estimated in the present investigation, was 63.3 (60-65) cm TL, but Last *et al*. (2016) reported that *R. annandalei* matured at 68.0 cm TL (males). In the same genus, White and Dharmadi (2007) reported that *R. jimbaranensis* and *R. penggali* males matured at 76.5 cm TL and 71.9 cm TL, respectively, in

Table 2. Prey composition of *R. annandalei* from Maharashtra, north-west coast of India

Prey item	% N	%M	% O	% I_{RI}
Crustacea				
Solenocera spp.	31.5	30.3	15.4	18.7
Parapenaeopsis stylifera	5.6	1.7	2.6	0.40
Parapenaeopsis sculptilis	1.9	7.9	2.6	0.50
Crabs	1.9	1.3	2.6	0.20
Squilla spp.	1.9	1.7	2.6	0.20
Other unidentified shrimp	29.6	32.0	38.5	46.6
Mollusca				
Loligo spp.	3.7	3.5	2.6	0.40
Teleostei				
Sciaenids	1.9	3.8	2.6	0.30
Other unidentified fishes	22.2	32.0	30.8	32.8

eastern Indonesia. However, the dataset of the present study showed that females and males matured between 60 and 65 cm TL.

Further, the examination of a large number of pregnant females (n =108), showed that this species had a mean number of two embryos (ranging between 2-11) and size at birth ranged between 25.0 and 30.0 cm TL. Raje (2006) recorded the maturity status of nine female *R. annandalei* and set forth the common number of young ones produced at a time as eight (four from either uterus), although the maximum recorded was twenty, and length at birth as 11.5 cm to 22.3 cm TL. The present study recorded specimens measuring >30.0 cm TL only in the fishery.

Pregnant females examined during pre-monsoon, monsoon and post-monsoon showed a wide range of embryonic developmental stages, *i.e*., from fertilised eggs to late-term embryos and appeared to have a non-seasonal reproductive cycle. The presence of fertilised eggs and embryos found in the uterus of some females indicated probable reproductive activity associated with coastal feeding as well as pupping in the coastal waters. According to Smith (1961), a fair number of mature females of *Rhinobatos annulatus* seggregated in the estuaries for pupping. Raje (2006) stated that the greatest reproductive activity appeared to be during the monsoon and post-monsoon months, as maximum gravid or parturient females were landed in September and October. Therefore, the parturition period appeared to be towards the end of the year and changes in the landings of juveniles measuring <50.0 cm TL during January to May explicitly support the observation made during the present study. Raje *et al*. (2007) reported the peak breeding season for the species as between September-October in the north-west coast of India and between August-November in south-west coast of India.

Previously, only a few reports provided basic information on the diet of this species. Raje (2006) suggested that *R. annandalei* fed on fishes (*Harpadon nehereus*, *Cynoglossus* spp., *Priacanthus hamrur* and *Trichiurus* spp.) and crustaceans (prawns and squilla). In the present study, *R. annandalei* was found to feed primarily on crustaceans (66.5%), teleosts (33.1%) and cephalopods (0.4%). Its major prey items included *Solenocera* spp. (%IRI=18.7), *P. sculptilis* (%IRI=0.5), *P. stylifera* (%IRI=0.4) and sciaenids (%IRI=0.4). The results indicated *R. annandalei* as a mesopredator that displayed both benthic and demersal feeding behaviour with a diet consisting predominantly of invertebrates. The typical coastal prey items found in the stomachs revealed that *R. annandalei* inhabited depths between 2-70 m.

A large scale survey of elasmobranchs in general and shark-like batoids in particular, is essential to document their level of susceptibility to being captured in a variety of fishing gears operating in particular geographical areas. Many guitarfish species are hindered by identification challenges and as indicated by the often outdated IUCN Red List assessments, the vast majority of guitarfishes are threatened, poorly known or both (Moore, 2017). The results of the present study will contribute significantly to an understanding of the species composition and exploitation in the trawl, gillnet and *dol* /bag net fisheries of Maharashtra, India. The study provides the first ever detailed information on biological observations including size and sex compositions, maturity, diet, length-weight relationship and occurrence of *R. annandalei* and also details of bycatch of this species from inshore fisheries operating off the north-west coast of India at depths of 2-70 m. The study documented the landing of shark-like batoids in multispecies and multi-gear regime in the region; the frequency of occurrence and the quantity of landings indicated the population size structure, demography (age at maturity and fecundity) and species abundance (Walker, 1998; Jabado, 2018). The biological knowledge of chondrichthians in Indian waters is not well documented and information is scarce (Akhilesh *et al*., 2013, Purushottama *et al*., 2018). The data on life history is very important for developing species specific management plans aimed at a precautionary approach to ecosystem based management and conservation of shark-like batoids, especially taking into account their role in the marine food web (Stevens *et al*., 2000; Mulas *et al*., 2015). Innovative approaches to conservation of guitarfish and elasmobranchs in the inshore areas of the developing world is required to ensure their long term survival (Moore, 2017).

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