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Biology of the cleftbelly trevally *Atropus atropos* (Bloch and Schneider, 1801) from Ratnagiri coast of India

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Abstract

The cleftbelly trevally *Atropus atropos* (Bloch and Schneider, 1801) is one of the important carangid species landed mostly as trawl bycatch along Ratnagiri coast. Investigations were carried out on *A. atropos* with respect to length-weight relationship, condition factor, morphometrics, feeding and reproductive biology. The length-weight relationship indicated negative allometric growth in *A. atropos*. Morphometric measurements showed significant correlation with total length. The gut content analysis revealed *A. atropos* to be a carnivore fish feeding mainly on *Acetes* spp., small teleostean fishes, cephalopods, and squilla. Sex ratio showed dominance of males. Gonadosomatic index and maturity studies indicated that *A. atropos* has a protracted spawning season extending from May to December. Length at sexual maturity for females was estimated to be 171 mm. Fecundity ranged from 16458 to 138688 eggs with an average of 70097 eggs. Ova diameter studies showed that *A. atropos* spawns twice in a protracted spawning season.

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Introduction

Family Carangidae is a highly diverse group of important food fishes including jacks, trevallies, scads, queenfishes, runners, pompanos and amberjacks. The family is made up of four sub-families represented by 32 genera and 140 species (Nelson, 2006). Carangids can be found in all tropical as well as subtropical marine seas worldwide, and occasionally in temperate regions (Nair *et al.*, 2018). They are extensively spread in the Atlantic, Pacific, and Indian oceans (Nelson, 2006). Carangids occur along both the east and west coasts of India. They are mostly confined in their distribution to shallow waters upto a depth of 60 m (Nair, 2000). The carangid catches are dominant during the monsoon season, especially along the north-east and south-west coasts of India (Sivakami *et al.*, 1996). About 62 species from 20 genera have been reported from Indian waters (Joshi *et al.*, 2011). Carangids are mostly caught by trawls, purse-seines and drift gillnets apart from boat seines, gillnets and hooks and line (Bandkar *et al.*, 2020,2022). In India, the total production of carangids stood at 1.8 lakh t contributing about 4.83% to the total marine fish landings of the country (Anon., 2020). The cleft belly trevally, *Atropus Atropos* (Bloch and Schneider, 1801) is an important species belonging to family Carangidae. *A. atropos* is found in tropical and subtropical waters of the Indo-Pacific, from the south-western to the southern regions of Taiwan (Lin and Shao, 1999). In India, *A. atropos* is distributed along the entire coastline, however it is abundant in the states of Gujarat, Maharashtra, Karnataka, Kerala and Tamil Nadu. Studies on length-weight relationship of *A. atropos* were carried out by Reuben *et al.* (1992), Raje (1994), Kasim (1999), Qamar and Panhwar (2017), Rajesh *et al.* (2017b) and Rahman *et al.* (2021); fishery and biology was studied from Gujarat coast by Raje (1994); maturation and spawning studies by Rajesh *et al.* (2018); biology and stock assessment by Reuben *et al.* (1992); Kasim (2003) and food and feeding habits by Rajesh *et al.* (2017a). Reports on the biology of *Atropus atropos* from Indian waters are very few and no work has been carried out on the species from Ratnagiri coast of India. Hence this study on the length-weight relationships, morphometrics, reproductive biology and trophodynamics of *A. atropos* from Ratnagiri was undertaken. The biological studies on the species will yield vital information on growth, feeding habits, reproductive potential, maturity and spawning, which can form useful inputs for promulgating management plans for sustainable fisheries of the species from the region.

Materials and methods

A total of 589 samples of *Atropus atropos* were collected from commercial trawl bycatch landed at Mirkarwada fish landing centre (16.9800° N; 73.3000° E) in Ratnagiri, Maharashtra, at weekly intervals from December 2021 to October 2022. Species identification was carried out as per Fischer and Bianchi (1984).Total length (cm) and body weight (g) for each individual were recorded. Nineteen morphometric measures were regressed on the total length (Zar, 2005). The length-weight relationship (LWR) was calculated by linear regression on the transformed equation: log W = log a + b log L, where W is body weight (g), L is length (cm), *a* is intercept and *b* is slope of linear relationship analysis (Froese, 2006). t-test was employed to check whether estimated '*b*' values differed significantly from 3, which would indicate the type of growth to be isometric, negative or positive allometric. Relative condition factor (Kn) was calculated as per Le Cren (1951):

$$Kn = \frac{W}{Wc}$$

where, Kn is relative condition factor, W is observed weight of the fish and Wc is estimated weight of the fish.

The fishes were dissected and the sex and the stage of maturity were noted. Data on sex ratio were analysed by χ^2 (chi square) test to find out if either sex was dominant. Gonads were excised out and weighed using analytical balance to the nearest 0.001g, and preserved in 4% neutral formalin for further studies. The gut content analysis was carried out as per Hynes (1950) using Frequency of Occurrence and Points (volumetric) methods. Gonadosomatic index (GSI) was estimated as per Bal and Rao (1984). To define the different maturity stages, colour and size of the ovary and size of the ova were taken into account. The female maturity stages of *A. atropos* were classified using a five-point maturity scale used in the case of multiple spawners (Holden and Raitt, 1974) as immature (I), maturing (II), matured (III), gravid (IV) and spent (V) based on the observations made at the laboratory on physical appearance such as colour and abdominal cavity occupied by gonads as well as ova diameter. The mean length at sexual maturity (Lm) was estimated as per King (1995). Fecundity was determined as per Sinha (1995). Ova diameter of intra ovarian eggs was measured from subsamples taken from anterior, middle and posterior regions of the ovary using ocular micrometer. Frequency polygons were drawn for all stages of maturity for ascertaining spawning frequency.

Results and discussion

Length-weight relationship and morphometrics

Estimated parameters of the length-weight relationship including total length (TL) and total weight (TW), number of specimens (n), values of parameters '*a*' and '*b*' and the coefficient of determination (r^2) are given in Table 1. The generalised length-weight relationship of *A. atropos* along the Ratnagiri coast was determined as $W = 0.0358\ L^{2.7234}$. The estimated 'b' values in the present study indicated negative allometric growth (p [illegible] 0.05) which is similar to the findings of Reuben *et al.* (1992), Raje (1994), Kasim (1999), Qamar and Panhwar (2017) and Rajesh *et al.* (2017b). Rahman *et al.* (2021) reported that *A. atropos* from the Bay of Bengal, off Bangladesh exhibited positive allometric growth based on estimated *b* values. The '*b*' values in the present study are found to be in the expected range of 2.5 to 3.5 (Froese, 2006). Variability in the length-weight relationship can be attributed to several factors such as sex, gonad maturity, stomach fullness, sample size, size range cover and habitat (Krishnamoorthi, 1971; Froese, 2006; Bandkar *et al.*, 2022).

Comparison of the nineteen morphometric measurements with the total length (TL) of the species yielded a moderate to high degree of correlation ranging from 0.7131 to 0.997 (Table 2). The morphometric characters compared in the present study would prove helpful for comparison with *A. atropos* in other geographical areas. Morphological variability among different geographical populations could

Table 1. Estimated length-weight relationship for *A. atropos* off Ratnagiri coast

Group	N	TL range (cm)	Body weight range (g)	$W = aL^b$ parameters		
				a	b	r^2
Males	300	11.2-25.4	23.9-222.5	0.0361	2.7186	0.9816
Females	247	11.4-25	26.1-221.6	0.0309	2.7770	0.9862
Indeterminates	42	10-12.1	20.9-35.2	0.0460	2.6318	0.6121
Total (combined)	589	10-25.4	20.9-222.5	0.0358	2.7234	0.9848

N-Number of specimens; *a*-Intercept; *b*-Slope of linear relationship; r^2-Coefficient of determination be attributed to the different genetic structure of populations and to different environmental conditions prevailing in each geographical area (Mamuris *et al.*, 1998). Therefore, the animals, with the same morphometric measurements are often assumed to constitute a stock (Waldman *et al.*, 1988) and has been used widely in fishery stock differentiation studies (Avsar, 1994; Natarajan *et al.*, 2011).

Condition factor

Condition factor was observed to be minimum in February and maximum in August (Fig. 1). The values of condition factor were higher during the spawning season. Raje (1994) observed that the variation in Kn values in females of *A. atropos* was more strongly associated with gonad maturity. Rajesh *et al.* (2017b) observed monthly variation in condition factor (Kn) of *A. atropos* from Mangalore coast and reported that Kn values were roughly comparable in both sexes. Alteration in the general condition of the fish can be due to changes in the gonad cycle, including the state of fullness of the alimentary canal (Weatherly, 1979). The

Table 2. Comparison between various morphometric characters of A. atropos

Regressions tested	Observations (n)	Coefficient of Correlation (r)
TL *vs* Standard length	589	0.9925
TL *vs* Fork length	589	0.997
TL *vs* Head length	589	0.9717
TL *vs* Snout length	589	0.8746
TL *vs* Eye diameter	589	0.9492
TL vs First dorsal base length	589	0.9078
TL *vs* Second dorsal base length	589	0.7131
TL *vs* Anal base length	589	0.9849
TL *vs* First pre-dorsal length	589	0.8833
TL *vs* Second pre-dorsal length	589	0.9787
TL *vs* Pre-anal length	589	0.9822
TL *vs* Pre-pelvic length	589	0.9423
TL *vs* Pre-pectoral length	589	0.9747
TL *vs* Body depth	589	0.9867
TL *vs* Pectoral fin length	589	0.9682
TL *vs* First dorsal height	589	0.8124
TL *vs* Second dorsal height	589	0.9013
TL *vs* Anal height	589	0.9211
TL *vs* Pelvic height	589	0.9467

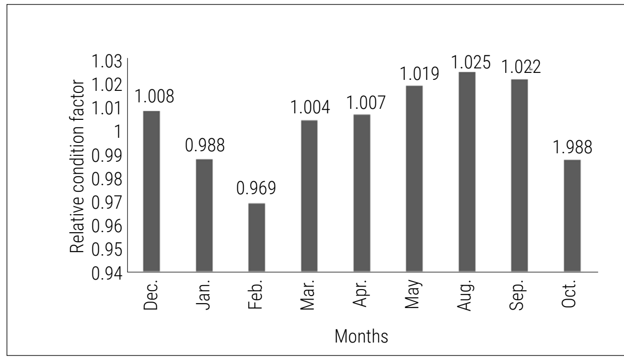

Fig. 1. Month-wise relative condition factor in *A. atropos*

Kn value is influenced by various factors like environment, feeding intensity, food type, amount of fat or muscular developments, breeding cycle, age, sex and development stage of gonads of fish (Abowei, 2010; Pawase *et al.*, 2020).

Food and feeding biology

The results of gut content analysis by Frequency of Occurrence and Points (volumetric) method is given in Fig. 2 and 3 respectively. The Index of Preponderance is presented in Table 3. Table 4 gives a comparative account on the feeding habits of *A. atropos* and other species of trevallies reported by different authors. The carnivorous feeding habit of *A. atropos* from Ratnagiri coast is in conformation with the earlier reports of Fischer and Bianchi (1984), Raje

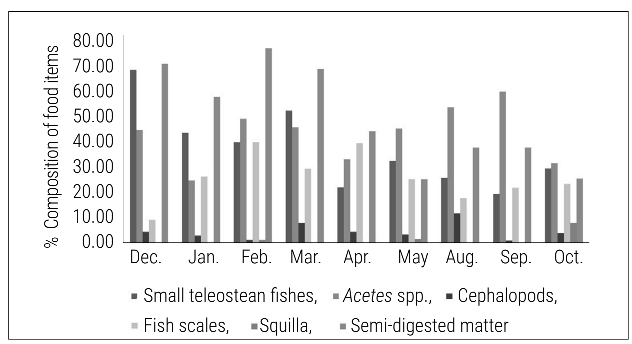

Fig. 2. Percentage composition of food items of *A. atropos* during different months by Frequency of Occurrence method

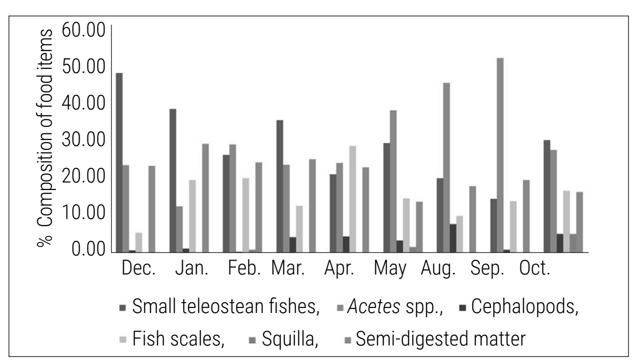

Fig. 3. Percentage composition of food items of *A. atropos* during different months by Points (volumetric) method

(1994) and Rajesh *et al.* (2017a). The variations in food items consumed by a fish during different months may be due to the dominance of respective food items in different regions (Bandkar *et al.*, 2022). Smaller and moderate size fishes of *A. atropos* from Ratnagiri in the present study had *Acetes* spp., semi-digested matter, fish scales and cephalopods in their stomach, whereas the bigger individuals mainly had small teleostean fishes and squilla. Carangids feed on planktonic crustaceans in the early stages of their life and on fish juveniles in the later stages (Sivakami, 1996). Food preference observed in individuals of different size groups can be attributed to the size and availability of prey organisms, mouth size and life history traits (Garcia *et al.*, 2018; Batool and Siddiqui, 2020).

The feeding intensity in *A. atropos* was generally observed to be higher in maturing and spent individuals and lower in spawners in the present study. Sivakami (1996) noted that the feeding intensity in carangids was more in immature and juvenile fish and less in breeders. Venkataramani and Natarajan (1988) observed that in *Seriolina leptolepis*, maturing and spent recovering fishes fed more than juveniles and matured groups. The highest percentage of full stomachs in *A. atropos* was observed during post-spawning months and empty stomachs were noted during spawning season. However, individuals with full stomachs were also noted in August which possibly included spent and immature individuals. Similarly, low feeding intensity was also observed in maturing pre-spawners during April, contradicting the general observation that increased feeding takes place in maturing individuals. This may be related to the sparse availability of prey food in the environment. A similar condition with respect to spawning and feeding intensity was observed by Kagwade (1968) in *Caranx kalla* from Calicut coast and Kende (2016) in *Thryssa mystax* from Ratnagiri coast. Raje (1994) reported that the low feeding intensity was associated with the spawning period only during certain months in which females were both in maturing and matured condition.

Reproductive biology

In the present study, the average sex ratio was found to be 1:0.82. However, significant difference ($p<0.05$) was noted in the sex ratio during December and October only (Fig. 4). The results confirmed the findings of Raje (1994). Rajesh *et al.* (2018) reported the dominance of females from Mangalore coast in *A. atropos*. The change in the sex ratio from the Mendelian ratio of 1:1 may be caused by partial segregation of mature forms through habitat preferences (Reynolds,

Table 3. Index of Preponderance (IP) of food items in the stomach of *A. atropos*

Food items	Percentage of occurrence (Oi)	Percentage of volume (Vi)	Oi Vi	IP	Grade
Acetes spp.	42.58	30.28	1289.36	33.99	I
Small teleostean fishes	36.62	28.91	1058.65	27.91	II
Semi-digested matter	48.76	21.13	1030.05	27.15	III
Fish scales	25.61	15.58	399.075	10.52	IV
Cephalopod	4.73	3.22	15.2246	0.40	V
Squilla	1.26	0.88	1.11747	0.03	VI

Table 4. Food composition of *A. atropos* and other species of trevallies from different localities

Species	Locality	Main food item	Feeding habit	Author
A. atropos	Western Indian Ocean	Shrimps, copepods, decapod crustaceans and small fish	Carnivorous	Fischer and Bianchi (1984)
A. atropos	Veraval, Gujarat	*Acetes* spp., cephalopods, teleosts, squilla and copepods	Carnivorous	Raje (1994)
Caranx ignobilis	Tamil Nadu	Juveniles of sardines, anchovies, and other finfishes, shrimps, crabs instars, amphipods, *Decapterus* sp., other carangids, threadfin breams, lizard fishes, silverbellies, goatfishes and crabs	Carnivorous	Abdussamad *et al.* (2008)
A. atropos	Mangalore, Karnataka	*Acetes* spp., semi-digested matter, fish juveniles, teleosts, cephalopods, and copepods	Carnivorous	Rajesh *et al.* (2017a)
Seriolina nigrofasciata	South-west coast	Teleosts, cephalopods and crustaceans	Carnivorous	Rajesh *et al.* (2019)
A. atropos	Ratnagiri	*Acetes* spp., small teleostean fishes, cephalopods, fish scales, squilla and semi-digested matter	Carnivorous	Present study

1974), due to migration (Collignon, 1960) or behavioural differences between sexes (Polonsky and Tormosova, 1969) thus rendering one sex to be more easily caught than another. The dominance of either sex might be possible due to selectivity of gear, vulnerability of either sex to capture and variation in size at first capture (Pawase *et al.*,2020).

GSI was noted to be higher during the period May to December indicating the occurrence of more ripe individuals (Fig. 5). Individuals with ovaries in Stage III (Matured) and Stage IV (Gravid) were observed to be maximum during this period (Fig. 6). It can be inferred from the maturity studies and GSI studies that *A. atropos* has a prolonged spawning season extending from May to December along Ratnagiri coast. Reuben *et al.* (1992) observed the spawning period of *A. atropos* from north-west coast to be around November or December. Raje (1994) noted that *A. atropos* from Veraval coast had a prolonged spawning period and spawning took place twice in the spawning season. The spawning season of *A. atropos* from the Gujarat coast was reported to be from May to September by Kasim (1999). Spawning of *A. atropos* along the north-west coast took place in November and December (Kasim, 2003). Based on the GSI and maturity studies on *A. atropos* from Mangalore coast, Rajesh *et al.*

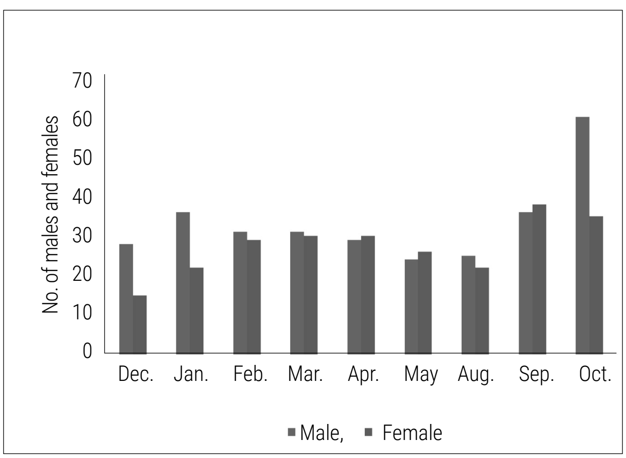

Fig. 4. Monthly variation in numbers of male and female fish in *A. Atropos* samples collected during the study

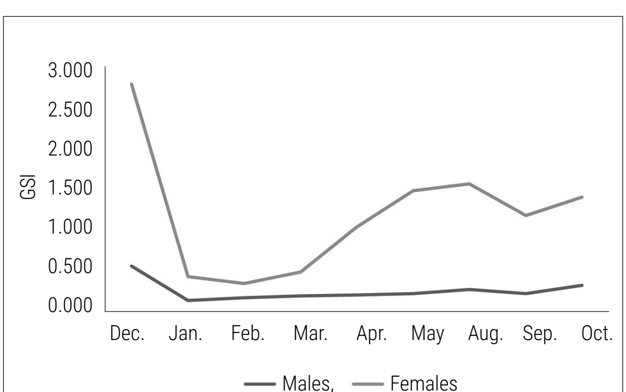

Fig. 5. Monthly GSI trend in males and females of *A. atropos*

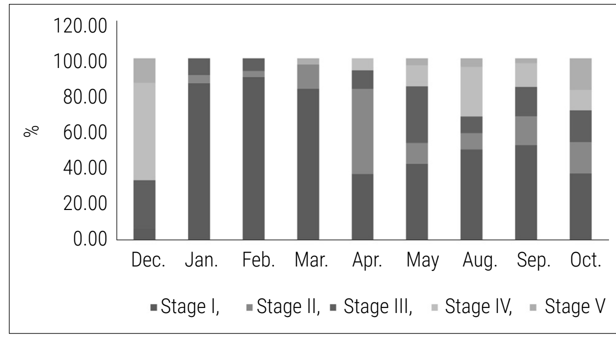

Fig. 6. Monthly variation in maturity stages (%) in females of *A. atropos*

(2018) observed that *A. atropos* is a prolonged spawner spawning twice in a season from September to December and February to May. The variation in the spawning season of a fish could be attributed to spatial, environmental and stock level differences (Bandkar *et al.*, 2022).

A. atropos is found to be a moderately fecund fish with an average fecundity of 70097 eggs per individual. Raje (1994) reported that the fecundity of *A. atropos* from the Veraval coast ranged between 31432 to 372344 eggs per fish, with an average of 141515 eggs in sizes ranging from 165-253 mm. It was observed that the fecundity increased with an increase in the size of the fish. Similar trend in fecundity was reported by Kagwade (1968) for *Caranx kalla*. Rajesh *et al.* (2018) reported that the fecundity of *A. atropos* from Mangalore coast ranged from 33298 to 188675 eggs with an average of 94083 eggs. They observed the variation in fecundity with respect to both length and weight. The fecundity varies from species to species and within a species from one region to another in accordance with the reproductive potential of the stocks (Kende, 2016; Gurjar *et al.*, 2018; Pawase *et al.,* 2020; Bandkar *et al.*, 2022).

The appearance of two modes in Stage IV ovaries (Fig. 7) shows the possibility of *A. atropos* spawning two times in a spawning season along the Ratnagiri coast. Rajesh *et al.* (2018) reported the presence of two modes of mature ova in Stage VI of *A. atropos* from Mangalore coast and stated that *A. atropos* spawned twice in a spawning season.

The size at first maturity for females of *A. atropos* from Ratnagiri coast was estimated to be 17.1 cm (Fig. 8). Length at first maturity reported by different workers (Reuben *et al.*, 1992; Raje, 1994; Rajesh *et al.*, 2018) for *A. atropos* ranged from 16to 21 cm. Difference in size at first maturity within a species points possibly to the presence of distinct stock, variation in growth rate and maximum size reached by different species under the influence of environmental factors including availability of food (Sawant *et al*., 2017; Mahadwala, 2019; Pawase *et al*., 2020; Bandkar *et al*., 2022).

The present study provides vital information on morphometrics and length-weight relationship, feeding and reproductive biology of *A. atropos* from Ratnagiri coast. *A. atropos* was

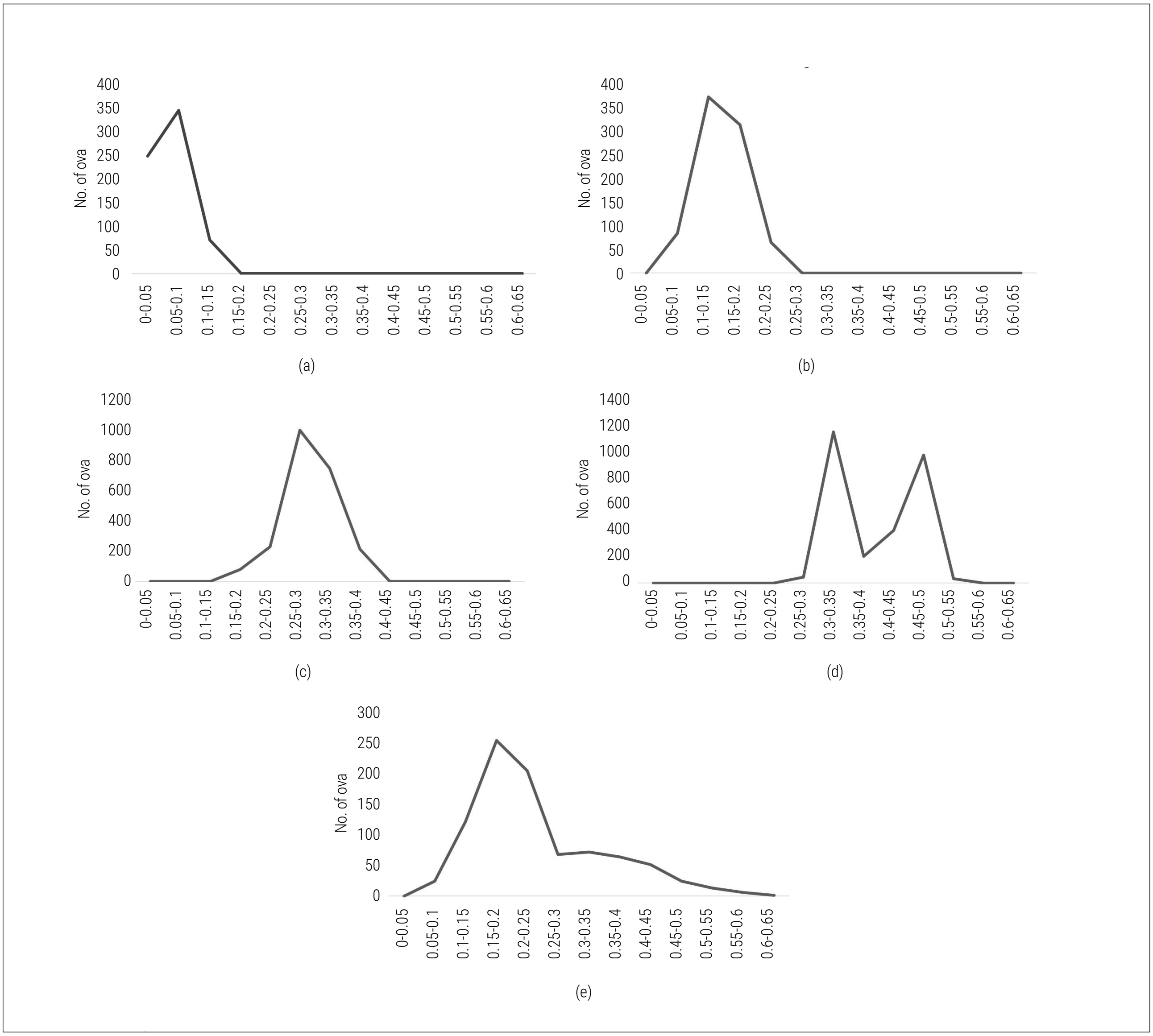

Fig. 7. Ova diameter trend in *A. atropos.* (a) Stage I, (b) Stage II, (c) Stage III, (d) Stage IV, (e) Stage V

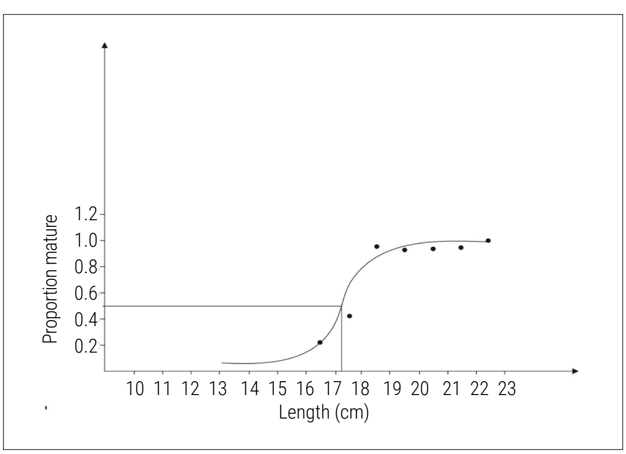

Fig. 8. Mean length at sexual maturity in females of *A. atropos* along Ratnagiri coast

found to be moderately fecund fish with a spawning season from May to December in the study region. The size at first maturity for females was estimated to be 17.1 cm. The morphometric results of this study can be used for stock identification of the species in Indian waters. This study provides an insight about the biology *of A. atropos* that can be effectively used to frame management policies for sustaining the fisheries of this species in the region.

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