



Feeding behaviour and reproductive biology of the shrimp scad *Alepes djedaba* (Forsskal, 1775) off Cochin coast, Kerala

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ABSTRACT

Food and feeding habits, sex ratio, spawning behaviour, size at first maturity, fecundity and ova diameter of the shrimp scad *Alepes djedaba* (Forsskal, 1775) exploited off Cochin coast, Kerala are presented in this study. *A. djedaba* is a pelagic carnivore, with a preference for fishes. Low gastrosomatic index (GaSI) values and very low feeding intensity during spawning season indicated poor feeding behaviour during the period. The sex ratio did not deviate from the expected 1:1 ratio. Size at first maturity was estimated to be 193 mm for male and 174 mm for female. Monthly gonadosomatic index (GSI) values, monthly distribution of gonadal maturation stages and ova diameter revealed that the species had a prolonged breeding season from June to September with a peak in July. Estimated absolute fecundity was 59,744 to 3,30,190 with an average of 1,94,965 eggs.

Keywords: *Alepes djedaba*, Fecundity, Feeding behaviour, Ova diameter, Sex ratio

Introduction

Carangids form important pelagic fishery resources contributing substantially (5.8%) to the total marine fish landings in India (CMFRI, 2015). The shrimp scad *Alepes djedaba* (Forsskal, 1775) belonging to the family Carangidae, is a shoaling pelagic fish, widely distributed in the Indo-Pacific region. It forms a major constituent of scads landed along Cochin coast, Kerala and has got good demand in the domestic market due to its affordable price. Though several species constitute the carangid fishery, *A. djedaba* assumes greater significance as it forms an important constituent in both, artisanal as well as mechanised fishery, along the Indian coast.

Information on biology of *A. djedaba* from Indian waters is scanty except, for a few reports. Feeding habits and breeding biology of the species was studied by Kuthalingam (1955) from Madras, Venkataramani *et al.* (1984) from Porto Novo, Sivakami (1990) from Cochin and Raje (1993) from Veraval coasts. El-Sayed (2005) estimated the growth, mortality and yield per recruit of the species from Abu Qir Bay, Egypt. Shuaib and Ayub (2011) studied some aspects of biology of the species from Pakistan coastal waters and Barr *et al.* (2014) reported on stock evaluation of *A. djedaba* from Arabian Gulf off Saudi Arabia. The present study focussed on the feeding and reproductive biology of *A. djedaba* off Cochin in south-west coast of India.

Materials and methods

Fish samples were collected randomly from landings at Munambam (10°10'57" N; 76°10'12" E), Kalamukku (9°59'00" N; 76°14'33" E) and Cochin (9°56'19" N; 76°15'44" E) fisheries harbours on a weekly basis during January 2012 to December 2013. A total of 605 fishes (315 males and 290 females) were collected for the analysis and total length and weight were recorded to the nearest 1 mm and 0.1 g respectively. For analysing the diet composition and feeding behaviour of the species, the guts were dissected out and length, weight and distension of the stomach were noted. The guts were classified as Gorged, Full, $\frac{3}{4}$ full, $\frac{1}{2}$ full, $\frac{1}{4}$ full, trace and empty based on the fullness of stomach and amount of contents present in the stomach (Pillay, 1952). Index of preponderance was calculated to get a clear idea about the food preferences, percentage frequency and occurrence of different food items in the diet (Natarajan and Jhingran, 1961).

Index of preponderance = $(V_i O_i) / (\sum V_i O_i) \times 10$
where, V_i = Percentage volume of different food contents;
 O_i = Percentage occurrence

Intensity of feeding was calculated from gastro-somatic index (GaSI) (Desai, 1970) and feeding behaviour was analysed from relative length of gut (RLG), which was expressed as the ratio of length of gut to the total body length (Al-Hussainy, 1949). Data on sex, stage of maturity, length, weight and appearance of gonads were collected

from the fish samples and gonads were transferred to Gilson's fluid for further analysis. Maturity stages were determined by macroscopic and microscopic examination of gonads and classified following Bensam *et al.* (1989). The length at first maturity (Lm) was estimated by plotting a graph of percentage of fishes in stage III and above against their respective length class. The spawning season was inferred from the values of GaSI and gonadosomatic index (GSI) (Vladykov, 1956; Hopkins, 1979). The sex ratio for different months was calculated and statistically tested by performing Chi squared (χ^2) analysis (Snedecor and Cochran, 1967). Ova diameters were taken from ovaries of stage III to stage VI by the method described by Antony Raja (1964) and the frequency polygons were constructed from these measurements. The measurements were taken with the help of an ocular micrometer, where 1 ocular micro division = 10.7 μ m. Fecundity was estimated from 15 ovaries (stage V and VI) of fishes in the length and weight range of 210-310 mm and 86.7-300 g, respectively. The ovaries were preserved in Gilson's fluid, and maturing and mature ova from a set of subsamples (weighing approximately 0.01g) were counted and fecundity was calculated using the following formula:

$$\text{Fecundity} = (\text{Total Weight of the ovary}) / (\text{Weight of sub sample}) \times \text{No. of ova in the sample}$$

The relation between fecundity to the total length, total weight and gonad weight were formulated by applying least square method:

$$F = aX^b$$

where F = Fecundity, a = Constant, b = Regression coefficient and X = Length/ Weight/Gonad weight of fish.

All statistical analyses were done using the SPSS 16.0 analytical software.

Results

Feeding intensity and diet composition

Out of 605 gut samples examined, 48.6% had empty stomachs. Empty stomachs were predominant in all months (Fig. 1) and in all length groups (Table 1), followed by poorly fed condition ('1/4 full' and 'trace' condition for their stomachs). The study indicated significant variation in feeding intensity within each sex ($F = 4.108, p < 0.01$), but no variation was observed between sexes ($p > 0.05$). In males, well fed fishes (with '3/4 full', 'full' and 'gorged' condition for stomachs) were more during pre-monsoon season and low during monsoon season (Fig. 2). In females too, maximum number of well fed individuals was noticed in pre-monsoon season while monsoon and post-monsoon seasons had comparable values (Fig. 3). In both

males and females, approximately similar proportions of poorly fed condition were noted in all the seasons whereas moderately fed condition was more in post-monsoon season.

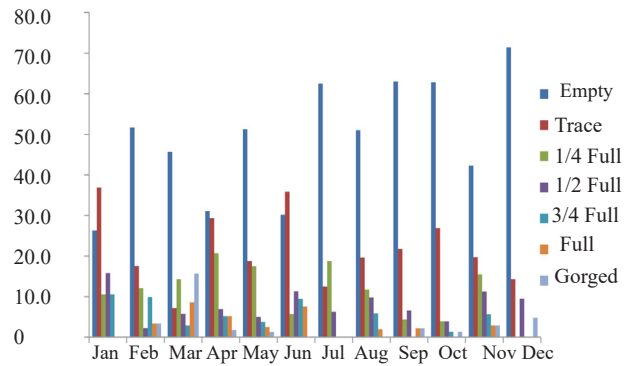


Fig. 1. Feeding intensity of *A. djedaba* during different months

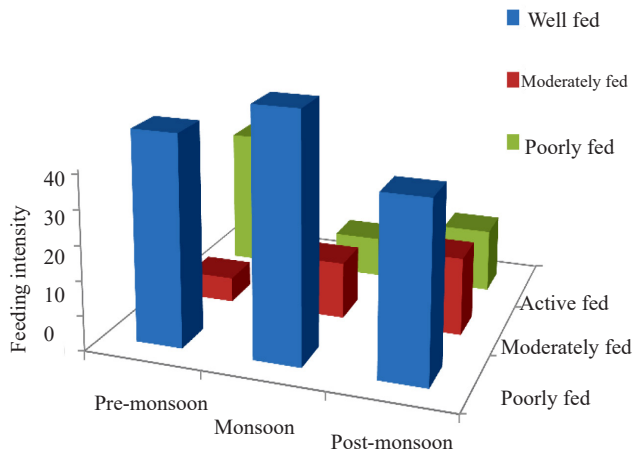


Fig. 2. Seasonal variation in feeding intensity of male *A. djedaba*

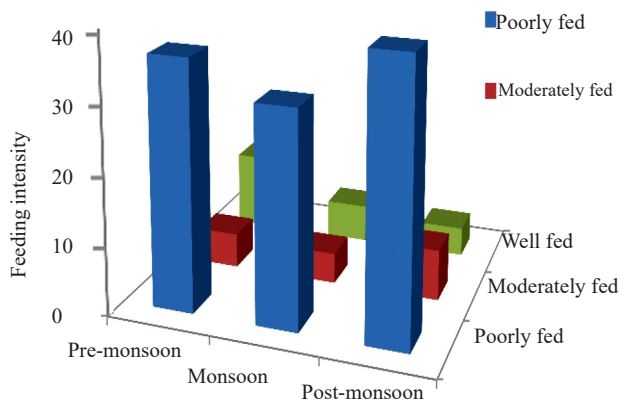


Fig. 3. Seasonal variation in feeding intensity of female *A. djedaba*

Table 1. Feeding intensity (%) of *A. djedaba* for different size class

Length class (mm)	Empty	Trace	1/4 full	1/2 full	3/4 full	Full	Gorged
120-139	52.6	36.8	10.5	—	—	—	—
140-159	47.3	26.4	12.1	3.3	5.5	4.4	1.1
160-179	58.1	23.9	6.0	3.4	5.1	0.9	2.6
180-199	44.4	23.2	11.1	8.1	6.1	4.0	3.0
200-219	54.1	16.4	13.1	11.5	3.3	1.6	—
220-239	40.8	20.4	18.4	10.2	8.2	2.0	—
240-259	39.4	28.8	18.2	9.1	4.5	—	—
260-279	60.0	14.0	12.0	8.0	4.0	—	2.0
280-299	35.4	12.5	14.6	16.7	4.2	8.3	8.3
300-319	46.5	11.6	9.3	4.7	4.7	9.3	14.0
320-339	70.0	—	—	—	—	—	30.0

Analysis of stomach contents revealed that the diet of *A. djedaba* consisted of fishes, shrimps, shrimp larvae, ostracods and semi-digested matter. Fishes dominated in the diet, *Stolephorus* spp. being the most preferred, with an index of preponderance of 89% followed by semi-digested matter (9.3%), shrimps (1.16%), ostracods (0.28%) and shrimp larvae (0.09%) (Table 2). Fishes were more preferred in all the months (Fig. 4) and in all the length groups (Table 3) while others were found to be a part of the diet during pre-monsoon and post-monsoon seasons.

Relative length of gut (RLG) and gastroscopic index (GaSI)

The RLG was very low for both the sexes (Fig. 5; Table 4), ranging from 0.03 to 0.3 for male (with an average

Table 2. Annual Index of preponderance (IP) of different food items of *A. djedaba*.

Food items	% Occurrence	% Volume	% IP
Fishes	44.5	80.6	89.14
Shrimps	7.6	6.1	1.16
Shrimp larvae	2.0	1.9	0.09
Ostracods	5.1	2.2	0.28
Digested matter	40.8	9.2	9.32

Table 3. Index of preponderance of different food items in different size groups of *A. djedaba*

Length class (mm)	Fishes	Shrimps	Shrimp larvae	Ostracods	Digested matter
120-139	0.0	0.0	0.0	0.0	100.0
140-159	47.3	2.6	0.0	0.0	50.1
160-179	82.1	1.8	0.0	0.3	15.8
180-199	89.4	2.7	0.3	1.3	6.3
200-219	55.1	12.0	0.8	0.3	43.8
220-239	35.0	0.7	1.8	19.4	43.1
240-259	55.8	1.6	0.0	0.8	41.8
260-279	84.0	0.0	0.1	0.0	15.9
280-299	98.2	1.8	0.3	0.0	2.0
300-319	99.4	0.1	0.0	0.0	0.5
320-339	100.0	0.0	0.0	0.0	0.0

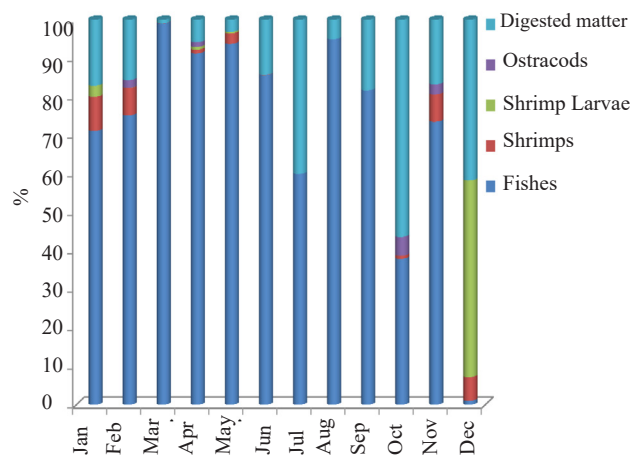


Fig. 4. Index of Preponderance of different food items during different months

value of 0.17) and 0.04 to 0.26 for female (with average value of 0.16). The study showed significant variations in different months ($F= 4.646, p<0.01$) and for different length class of fishes ($F = 1.669, p<0.01$); however, no definite pattern in variations were noticed.

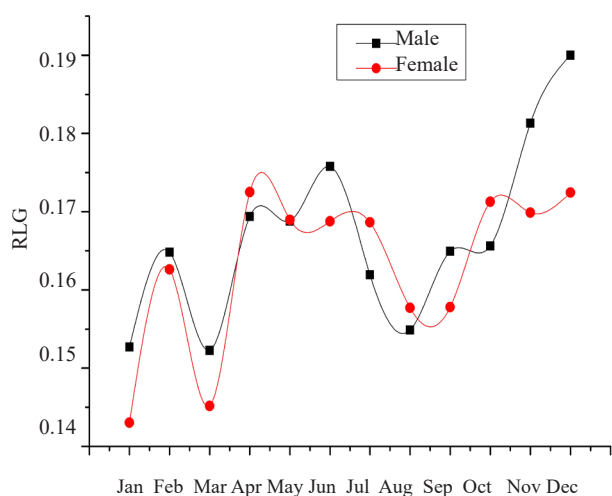


Fig. 5. RLG values of male and female *A. djedaba* for different months

Table 4. Relative length of gut for different size groups of *A. djedaba*

Length class (mm)	Male (Mean ± SD)	Female (Mean ± SD)
115-134	–	0.15 ± 0.05
135-154	0.16 ± 0.04	0.15 ± 0.04
155-174	0.17 ± 0.03	0.17 ± 0.02
175-194	0.16 ± 0.03	0.16 ± 0.02
195-214	0.17 ± 0.03	0.16 ± 0.03
215-234	0.16 ± 0.04	0.17 ± 0.02
235-254	0.16 ± 0.02	0.17 ± 0.02
255-274	0.17 ± 0.03	0.17 ± 0.03
275-294	0.17 ± 0.03	0.16 ± 0.02
295-314	0.19 ± 0.05	0.18 ± 0.03
315-334	0.18 ± 0.05	0.17 ± 0.02

Monthly GaSI values (Fig. 6) showed highly significant variation ($F = 4.119, p < 0.01$). This study recorded a minimum GaSI value of 0.03 during October and a maximum value of 11.63 during February for males; 0.36 during January and 11.31 during March for females. But for males, most of the high GaSI values were recorded during March (pre-monsoon season) and low values were recorded during the onset of monsoon and post-monsoon seasons (from August to October). Female fishes also showed high values during pre-monsoon season and low values during onset of monsoon and post-monsoon seasons. These seasonal variations were significant for both male ($F = 9.263, p < 0.01$) and female fishes ($F = 4.731, p < 0.01$). ANOVA followed by Tukey's HSD analysis clearly indicated significant difference in the variations in GaSI values in pre-monsoon season from that of monsoon and post-monsoon seasons ($p < 0.05$); but variations in post-monsoon and monsoon seasons did not differ significantly.

Only female fishes showed significant variation in GaSI with respect to the maturity stage of the gonads ($F = 4.057, p < 0.01$). GaSI values also varied significantly according to the size of the fish ($F = 1.644$, for male; $F = 1.656$ for female, $p < 0.01$). Moderate sized fishes of length 195 to 275 for male and 235 to 275 mm for females showed low values. In males, large fishes of length 275 to 335 mm had high GaSI values. But in females both large (275 to 315 mm) and small (155 to 195 mm) fishes showed higher GaSI values (Fig. 7).

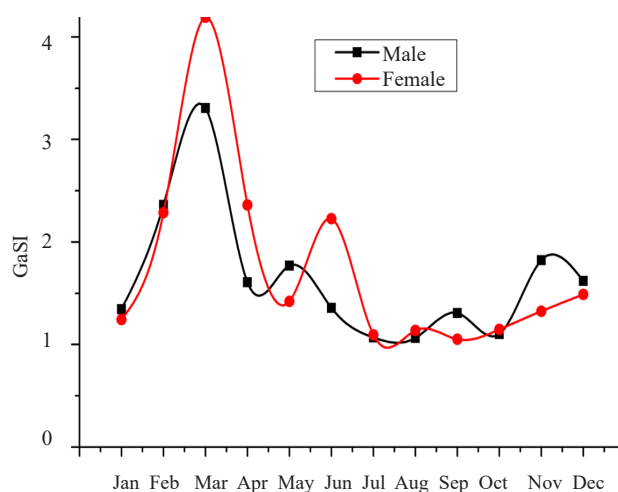


Fig. 6. Monthly GaSI values of male and female *A. djedaba*

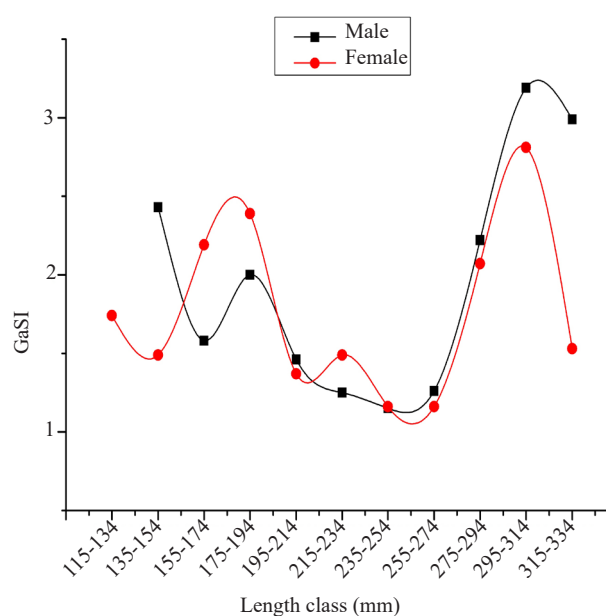


Fig. 7. Length-wise GaSI values of male and female *A. djedaba*

Maturity stages of gonads

Male and female gonads of *A. djedaba* were classified into different maturity stages as:

Stage I (Immature): Ovary very small, transparent and light pink in colour. Eggs not visible; testes thin like a thread and white in colour.

Stage II (Early maturing): Ovary and testes slightly enlarged, thick and translucent; occupied 1/4th of the body cavity

Stage III (Maturing): Testes and ovary opaque occupying about 1/2 of the body cavity. Ovary yellowish pink in colour with small ova and they started to develop the yolk.

Stage IV (Late maturing): Testes and ovary slightly enlarged and occupied more than 3/4th of the body cavity. Ovary yellowish in colour with opaque eggs; testes white in colour.

Stage V (Mature): Ovary and testes occupying almost the entire body cavity. Ovary brighter yellowish in colour with blood capillaries. Both opaque and transparent ova found in the ovary.

Stage VI (Ripe): Ovary and testes fully enlarged and milt oozed out with slight pressure. Ovary with large and transparent ova and very few opaque ones.

Stage VII (Spent): Both ovaries and testes shrunken, blood shot and occupied 1/2 of the body cavity. Ovaries dark reddish in colour; partially spent (VII a) with a batch of mature ova and fully spent (VII b). Testes dull white in colour

Gonadosomatic index (GSI)

From the monthly analysis of GSI values, the monsoon season showed higher values which clearly depicts that spawning occurred during the monsoon season with a peak in July (GSI - 6.46 for male and 7.21 for female) (Fig. 8). Greater number of mature and ripe fishes was encountered during July, maturing fishes were found in June, August and September (Table 5). Immature fishes dominated during pre-monsoon season and also during October and November while spent fishes were encountered more during post-monsoon season. A steady increase in GSI was observed from January onwards with peak at monsoon season and a sudden fall in the values was observed in the post-monsoon period. Seasonal variations in GSI values were highly significant for both sexes ($p < 0.01$). ANOVA followed by Tukey's HSD analysis showed that all the seasons contributed to these variations ($p < 0.05$).

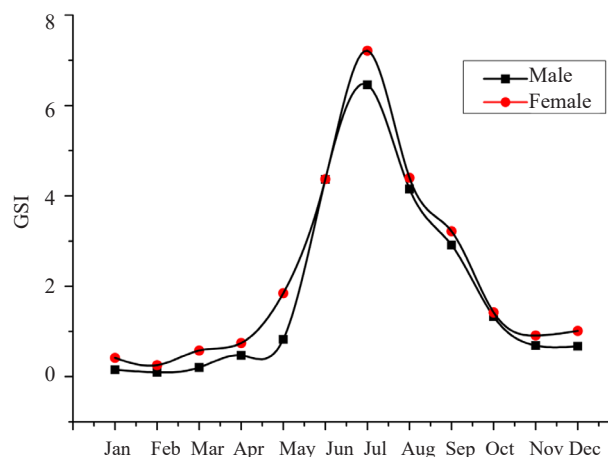


Fig. 8. Monthly GSI values for male and female *A. djedaba*

Length at first maturity (L_m)

The percentage occurrence of male and female mature fishes in different length classes are plotted in Fig. 9 and 10. In male fishes, length up to 145 mm were found to be immature and in case of females, smaller mature fishes were found in the length class 140-150 mm. The length at maturity was estimated to be 193 mm TL for males and 174 mm TL for females.

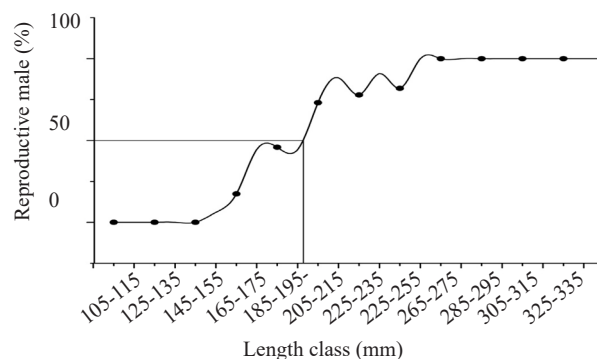


Fig. 9. Length at first maturity (L_m) for *A. djedaba* (Male)

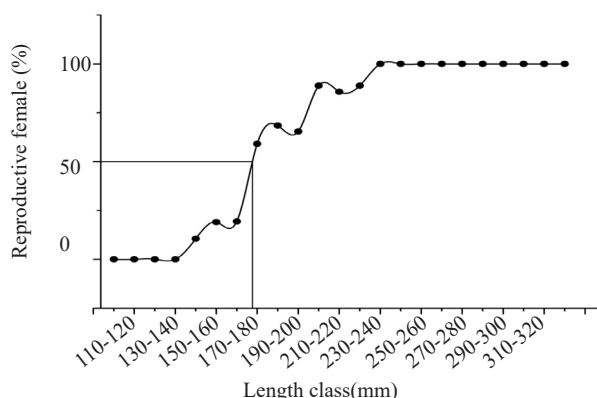


Fig. 10. Length at first maturity (L_m) for *A. djedaba* (Female)

Table 5. Month-wise distribution (%) of different stages of ovaries in *A. djedaba*.

Months	No. examined	Immature (I and II)	Maturing (III and IV)	Mature (V and VI)	Spent (VIIa and VIIb)
January	11	36	27	—	36
February	37	78	10.8	—	10.8
March	29	48.3	13.8	10.3	27.6
April	39	28.2	51.3	2.6	17.9
May	47	46.8	38.3	2	12.8
June	30	—	86.7	13.3	—
July	7	—	14.3	85.7	—
August	22	—	68.2	22.7	9.1
September	24	—	70.8	25	4.2
October	34	26.5	32.4	—	41.2
November	28	35.7	7	—	57
December	14	21.4	7	14.3	57

Sex ratio

The overall sex ratio for *A. djedaba* collected during the study period was 1.08:1 which did not deviate from the expected ratio of 1:1. The sex ratios for different months did not deviate significantly from the expected ratio throughout the year except in April and November (Table 6). Higher percentage of females (67%) were found in April while in November male dominance (69%) was prominent.

Ova diameter study

The frequency polygons for different stages (Fig. 11) showed that in stage III ovaries, the ova diameter ranged upto 128.4 µm with modes at 107 µm and 86 µm. Stage IV ovaries possessed maximum ova diameter of 428 µm with two modes at 321 µm and 268 µm. In stage V, the largest maturing ova measured 481.5 µm with two modes at 428 µm and 374.5 µm. In stage VI, the fully ripe ova formed two modes at 642 µm and 535 µm. The smallest ova in this stage measured 428 µm and the largest measured 685 µm.

Fecundity

Absolute fecundity ranged between 59,744 to 3, 30,190 eggs with an average of 1, 94,965 eggs. A significant positive correlation ($p < 0.01$) existed between fecundity and total

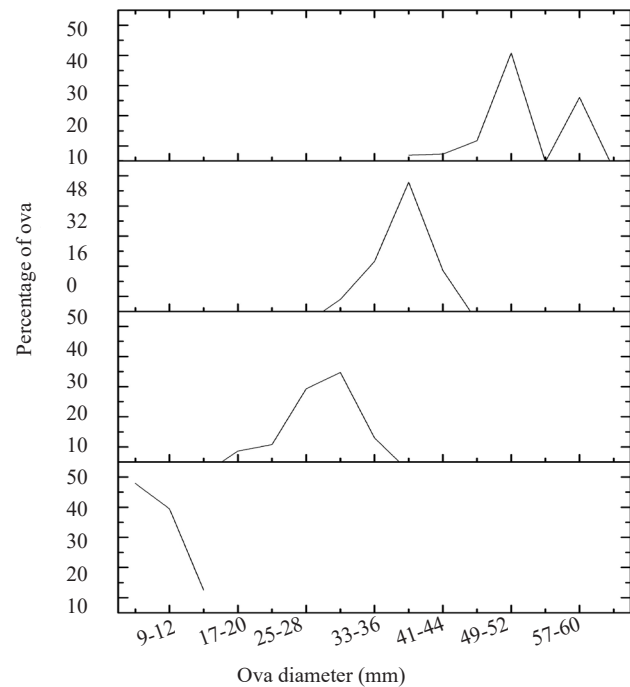


Fig. 11. Ova diameter frequency distribution in ovaries of different maturity stages in *A. djedaba*

Table 6. Sex ratio of *A. djedaba* during different months

Months	Sex ratio		χ^2 value
	Male (%)	Female (%)	
January	42.1	57.9	0.47
February	56.6	43.4	1.46
March	57.1	42.9	1.43
April	32.8	67.2	6.90 **
May	44.9	55.1	0.51
June	43.4	56.6	0.92
July	56.3	43.8	0.25
August	61.3	38.7	3.16
September	50.0	50.0	0.00
October	56.4	43.6	1.28
November	68.6	31.4	7.08 **
December	36.4	63.6	1.64

** Variation significant at $p = 0.01$

length ($r = 0.677$) as well as fecundity and body weight ($r = 0.756$). A strong correlation ($p < 0.01$) was also noted between fecundity and gonad weight ($r = 0.983$). The linear relationship of fecundity (F) with total length (TL), body weight (BW) and gonad weight (GW) were obtained as:

$$\log F = -3.3455 + 3.3992 \log TL (R^2 = 0.598)$$

$$\log F = 2.3201 + 1.2303 \log BW (R^2 = 0.667)$$

$$\log F = 4.1379 + 0.8988 \log GW (R^2 = 0.983)$$

Discussion

Studies on diet composition and food habits of fishes will decipher the trophic relations and help to understand the prey-predator interactions in an ecosystem (Hall *et al.*, 1995; Garvey *et al.*, 1998; Vander Zanden *et al.*, 2000). The length of the gut is directly related to the feeding habits of fishes; whether carnivores, herbivores or omnivores. The RLG value was found highest for herbivorous fishes and lowest (below unity) for carnivorous fishes (Dasgupta, 2004). According to Jobling (1995) the RLG was lower for piscivores than carnivores that feed on crustaceans, molluscs, worms and insects.

Carangids are pelagic carnivores, feeding on a variety of crustaceans and fishes (Nair, 2000). The present analysis showed that, *A. djedaba* is a carnivorous fish, feeding mainly on fishes and crustaceans. The RLG value below one is indicative of its carnivorous feeding habit. According to Sinha and Moitra (1976), there will be a change in RLG values of fishes at different stages of their life due to variation in food habits. No such changes were noticed in the present investigation which clearly indicated that the species strictly followed carnivorous food habit throughout their life.

Nikolsky (1963) categorised food of fishes into four types, on the basis of food preferences *i.e.*, (i) basic food: constitute major part of gut contents; (ii) secondary food: frequently encountered in the gut but in small quantities; (iii) obligatory food - found in the absence of basic food and (iv) incidental food - found rarely in the gut. Based on the variation in selection of food, fishes were classified as: (i) euryphagic - feeding on wide variety of food; (ii) stenophagic - feeding on few selected types of food and (iii) monophagic - feeding on a single type of food (Nikolsky, 1963). According to Sivakami (1990) *A. djedaba* fed on a variety of food items including fish juveniles, crustaceans such as ostracods, decapods, *Lucifer* spp., amphipods, cladocerans, stomatopods, insects and algae. Gut content analysis of the species from Porto Novo (Venkataramani *et al.*, 1984) and Veraval coasts (Raje, 1993) revealed that the diet was dominated by *Acetes* spp. and copepods whereas in fishes from Cochin coast, ostracods were

dominant (Sivakami, 1990). But the present investigation showed that, the species preferred a narrow range of food items and hence can be classified as stenophagic. Fishes formed the basic food item during all the seasons while shrimps formed the secondary food. During monsoon season only fishes were preferred. Preference for a particular food type during different seasons had a direct correlation with the seasonal abundance of the prey (Venkataraman, 1960; Sivakami, 1990). The species showed a preferential feeding behaviour on *Stolephorus* spp. and the same was observed by Sivakami (1990). In addition to *A. djedaba*, other carangids such as *Megalaspis cordyla* and *Decapterus dayi* also showed such a preferential feeding on *Stolephorus* spp. and hence it can be used as bait in hook and line to improve the fishery of these major carangid resources (Sreenivasan, 1974, 1979; Sivakami, 1990, 1995).

A review on the food habits of carangid fishes (Sivakami, 1996) revealed that food habits of fishes is one of the factors interconnected with reproductive periodicities. An earlier work by Kuthalingam (1955) reported that *A. djedaba* fed less during immature stages than when they are mature. But Sivakami (1990) observed that it had lower food volume during breeding season, which is in agreement with the present investigation.

Woodhead (1978) stated that the size at which 50% of fishes mature (L_m) was close to two-thirds of its final body length, and the estimated L_m for the species in the present study also agrees with this statement. The L_m from this study was close to the observation of Sivakami (1990) and Reuben *et al.* (1992). Sex ratio provides basic information required for reproduction and stock size assessment (Vicentini and Araujo, 2003). An earlier work from Cochin (Sivakami, 1990) reported predominance of males in most of the months while the present study showed an equal proportion of males and females throughout the year except in April and November. The availability of food directly influences the sex ratio and females require better environmental conditions for the development of gonads (Motlagh *et al.*, 2012).

The appearance and the relative size of gonads over time are most often used in fisheries studies to understand the reproductive cycles and time of spawning of marine fishes (King, 1995). Different environmental factors particularly temperature, day length and food supply directly influences the initiation of gonadal maturation and fecundity. The survival of a fish species by reproducing in a fluctuating environment determines its success (Moyle and Czech Jr., 2000). Ovaries are usually examined to understand the various developmental stages. The occurrence of mature and ripe female fishes during June to September and high concentration of

spent fishes during October to December, indicates that *A. djedaba* has a prolonged breeding season extending from June to September. From the high GSR values for both sexes during these periods it was evident that the fish has an extended spawning period with a peak in July. Prolonged spawning of the species has been reported earlier (Sivakami, 1990; Reuben *et al.*, 1992; Raje, 1993). GSI is one of the most popular and simple instantaneous measure for estimating reproductive effort. Generally, GSI in female is higher than in males (Helfman *et al.*, 2009). In the present study too, females showed much higher values than males. But this is contrary to the report of Sivakami (1990) that higher GSI values were found for males during the breeding season. The immature fishes which were dominant in pre-monsoon season showed lower GSI than the spent fishes.

Most marine fishes spawn pelagic eggs and their diameter ranges from about 0.5 to 5.5 mm (Helfman *et al.*, 2009). *A. djedaba* had spherical eggs with diameter that ranged from 0.05 to 0.7 mm. It is possible to study the duration of spawning period by studying the dimensions of ova in different stages of maturity (Prabhu, 1956). All maturing and mature ovaries of the species consisted of intermediate sized ova with two prominent modes, which is indicative of a prolonged spawning period (Fulton, 1899). The occurrence of ova with varying diameters and two prominent modes clearly suggested that the species produced two batches of ova which were released simultaneously during the same breeding season.

In marine fishes, fecundity varies from one to two to tens of millions (Helfman *et al.*, 2009). The present study revealed that *A. djedaba* is a highly fecund fish and the fecundity showed positive linear correlations with total length, body weight and gonad weight. The results of the present study contribute valuable information about the feeding and reproductive behaviour of the species which will help to plan effective strategies for its sustainable exploitation.

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