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Reproductive biology and feeding dynamics of the shrimp scad *Alepes djedaba* (Forsskal, 1775) from Ratnagiri, central west coast of India

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ABSTRACT

The shrimp scad *Alepes djedaba* (Forsskal, 1775) belonging to family Carangidae is one of the important components of trawl bycatch landed at Ratnagiri, Maharashtra. Length-weight relationship, condition factor, morphometrics, feeding and reproductive biology of the species was investigated in the present study. Length-weight relationship indicated isometric growth in males, females and pooled individuals. All morphometric characters showed a moderate to high degree of correlation with total length. The qualitative and quantitative analysis of food revealed that *A. djedaba* is a carnivorous fish feeding mainly on *Acetes* spp., small fishes, copepods and shrimp larvae. The male:female sex ratio was found to be 1:0.85. Higher gonadosomatic index (GSI) values for females were observed during post-monsoon season. The ova diameter study indicated that *A. djedaba* follows a protracted spawning season with the individual spawning twice in a season. The absolute fecundity ranged from 15004 to 640800 eggs with an average of 309916 eggs. Length at sexual maturity for female fish was estimated to be 149 mm.

Keywords: Arabian Sea, Feeding biology, Pelagic fish, Spawning season, Tropical fish

Introduction

In India the total carangid fish production stood at 266621 t during 2019 contributing approximately 15.97% of the pelagic fish production (CMFRI, 2020). Carangid catches are dominant during the monsoon, especially along the north-east and south-west coasts of India (Sivakami *et al.,* 1996). They are mostly caught by trawls, purse seines and drift gillnets apart from boat seines, gillnets and hook and lines (Bandkar *et al.,* 2019). Family Carangidae is a highly diverse group consisting of fishes such as jacks, scads, trevallies, pompanos, amberjacks and queen fishes. The family is made up of the four subfamilies represented by 32 genera and 140 species (Nelson, 2006). Three genera namely *Megalaspis, Decapterus* and *Alepes* are commonly represented in the landings from India. The genus *Alepes* is constituted by the species *Alepes kalla*, *A. melanoptera, A. djedaba* and *A. vari. Alepes djedaba* (Forsskal, 1775) is found throughout the Western Indian Ocean (Fischer and Bianchi, 1984). Furthermore, in India, *A. djedaba* occurs in the 60-80 m depth along the entire coast. It is a highly migratory species showing amphidromous behaviour. *A. djedaba* occurs in shoals or small groups near inshore reefs (Blaber and Blaber, 1980). Larger fishes are consumed fresh, salted and dried in the coastal areas and undersized go for fish meal preparation (Bandkar *et al.,* 2019). Some reports exist on biological studies of *A. djedaba* (Sivakami, 1990; Raje, 1993; Osman and Al Abdulhadi, 2011; Shuaib and Ayub, 2011); length-weight relationship (Taskavak and Bilecenoglu, 2001; Abdurahiman *et al.,* 2004); morphometry, length-weight relationship and relative condition factor (Sajana and Bijoy, 2017); macro taxonomic characters for the field identification of genera and species (Abdussamad *et al.,* 2013) and migratory behaviour (Golani *et al.,* 2013; Artuz and Kubanc, 2014; Turan *et al.,* 2017). Information on biology of the species, including feeding habit, reproductive potential, maturity and spawning season will be helpful for framing management measures to sustain the landings of *A. djedaba* in the region. Information on the feeding and reproductive biology of *A. djedaba* from Indian waters is rare and no data from the central western part of India is available. Therefore, the present study was conducted to investigate the biological aspects of *A. djedaba* from Ratnagiri, a prominent landing centre along the north-west coast of India, in order to provide baseline data for future assessments of the species.

Materials and methods

The identification of *A. djedaba* was carried out as per Fischer and Bianchi (1984). A total of 803 specimens

of *A. djedaba* predominantly landed by trawl gear (cod end mesh size 40 mm), purse seines and drift gillnets apart from boat seines, gillnets and hook and lines were collected at weekly intervals during March 2018 to February 2019 from Ratnagiri (Arabian Sea), Central west coast of India (16°38'16.008N to 17°58'45.534N) except June and July due to 'closed season' along the entire west coast of India. Total length (cm) and body weight (g) were recorded for each individual. 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). A 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. Condition factor "Kn" was calculated as per Le Cren's (1951) formula:

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

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

The fish were dissected to identify the sex and stage of maturity. Data on sex ratio were analysed using χ^2 test to find the domination of sex, if any. Gonads were cut out, weighed using analytical balance to nearest 0.01 g and preserved in 5% neutral formalin for further study. Stomach contents were analysed by numerical method (Biswas, 1993). The number of each food item was recorded and expressed as percentage of the total number of all food items in the sample studied. Gonadosomatic index (GSI) was estimated as per Bal and Rao (1984). The female maturity stages were classified as immature (I), developing (II), maturing (III), mature (IV) and spent (V) based on physical appearance such as the colour of the ovary, size and length of gonads and the size of the ova. The mean length at sexual maturity (L_m) was estimated following King (1995). Fecundity was estimated by gravimetric method (Sinha, 1995). Ova diameter of intra-ovarian eggs was measured from ova taken from a small portion of the ovary from the anterior, middle and posterior region. The development of ova was studied using ocular micrometer. Frequency polygons of ova diameter in different stages of maturity were plotted.

Results

Length-weight relationship and morphometrics

Length-weight relationship of three groups *viz*, males, females and sexes pooled were calculated separately. The length range and sample size of each sex is given in Table 1. Estimated parameters of the LWR 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. Comparison of the nineteen morphometric indices with the total length (TL) of the species yielded a moderate to high degree of correlation ranging from 0.70 to 0.99 (Table 2).

Condition factor (K_n)

Condition factor is a value measuring the well-being and robustness of fish in numerical terms and is considered as an index of general well-being. In the present study, the condition factor for pooled individuals showed an increasing trend from August (1.12) to November (1.26) during the spawning season and declined thereafter (Fig. 1).

Food and feeding biology

The gut content analysis revealed that *A. djedaba* is a carnivorous species feeding mainly on *Acetes* spp., small

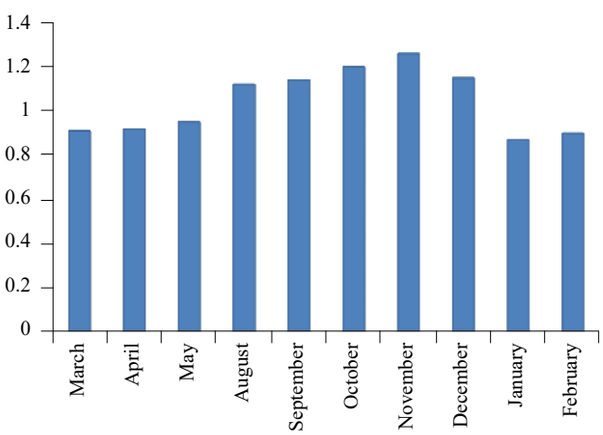

Fig. 1. Month-wise condition factor of *A. djedaba*

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

Group	n	TL range (cm)	Body weight range (g)	$W= aL^b$ parameters		
				a	b	r^2
Male	408	10.4 - 27	12 - 274	0.1628	2.8909	0.9607
Female	345	10.6 - 28.4	12 - 312	0.1475	2.9683	0.9684
Indeterminate	50	10 - 20.4	10 - 102	0.1245	3.1009	0.9785
Pooled sex	803	10 - 28.4	10 - 312	0.1540	2.9341	0.9651

n - Number of specimens; a - Intercept; b - Slope of linear relationship; r^2 - Coefficient of determination

Table 2. Comparison between various morphometric characters of *A. djedaba*

Regressions tested	Observations (n)	Coefficient of correlation (*r*)
TL *vs* Standard length	803	0.9832
TL *vs* Fork length	803	0.9949
TL *vs* Head length	803	0.9791
TL *vs* Snout length	803	0.7396
TL *vs* Eye diameter	803	0.8181
TL *vs* First dorsal base length	803	0.9203
TL *vs* Second dorsal base length	803	0.9851
TL *vs* Anal base length	803	0.9352
TL *vs* First pre-dorsal length	803	0.9830
TL *vs* Second pre-dorsal length	803	0.9836
TL *vs* Pre-anal length	803	0.9577
TL *vs* Pre-pelvic length	803	0.8704
TL *vs* Pre-pectoral length	803	0.9618
TL *vs* Body depth	803	0.9015
TL *vs* Pectoral fin length	803	0.9712
TL *vs* First dorsal height	803	0.7823
TL *vs* Second dorsal height	803	0.9385
TL *vs* Anal height	803	0.7013
Tl vs Pelvic height	803	0.7873

fishes, fish scales, copepods, shrimp larvae, cephalopod larvae, fish eggs, crustacean appendages and polychaetes (Fig. 2). Juveniles and moderate size individuals (100-210 mm) of *A. djedaba* were noted to feed on zooplankton dominated food including *Acetes* spp., shrimp larvae, copepods and fish eggs whereas the bigger individuals (210-280 mm) fed mainly on juveniles of small fishes. Maximum individuals of *A. djedaba* with empty stomachs were noted from October (46.84%) to November (37.04%) coinciding with the breeding season of the species. Individuals with full stomachs were mostly noted from March (22.5%) to April (26.92%).

Reproductive biology

In the present investigation, the overall male:female sex-ratio was found to be 1:0.85. Significant difference ($p<0.05$) was noted in the sex ratio during the months of April, August, September and January with males outnumbering the females. The GSI was used as a proxy for ascertaining the attainment and the extent of maturity of the gonads in the studied fish. Accordingly, in female specimens, highest GSI was recorded during the month of November with a single annual peak around the months of August through December. Similar GSI trends were observed for males (Fig. 3). 'Mature' females in their advanced stages of maturity (Stage IV) were encountered from August to December. 'Immature' (Stages I) and 'developing' (Stage II) females were encountered, in differing proportions, from January through May. 'Maturing' (Stage III) females were prominent in March and April and from August to October. 'Spent' (Stage V) specimens were observed from November through February (Fig. 4). The maturity stages were not entirely discrete as some degree of overlap with respect to periodicity was evident. During the breeding period, a total of 30 ovaries of either stage III or stage IV were collected to calculate the fecundity. In the present study, the absolute fecundity of *A. djedaba* ranged from 15004 to 640800 eggs with an average of 309916 eggs. Ova diameters recorded at different stages of oocyte development are given in Table 4. In all maturity stages, the ova diameters progressed in a unimodal fashion barring the Stage IV ovaries, which displayed two modes. As expected, the ova diameters progressed with the maturity stages and their modal values differed

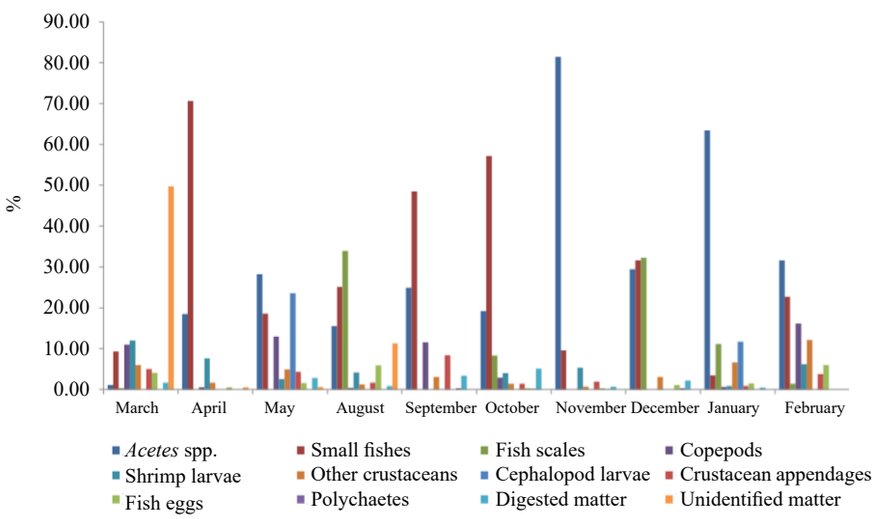

Fig. 2. Percentage composition of food items of *A. djedaba*

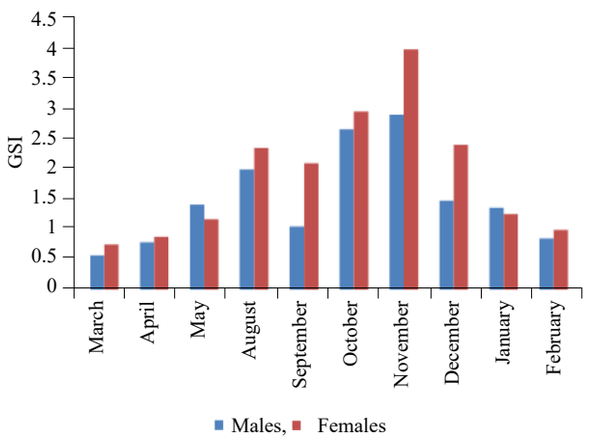

Fig. 3. Monthly GSI trend in males and females of *A. djedaba*

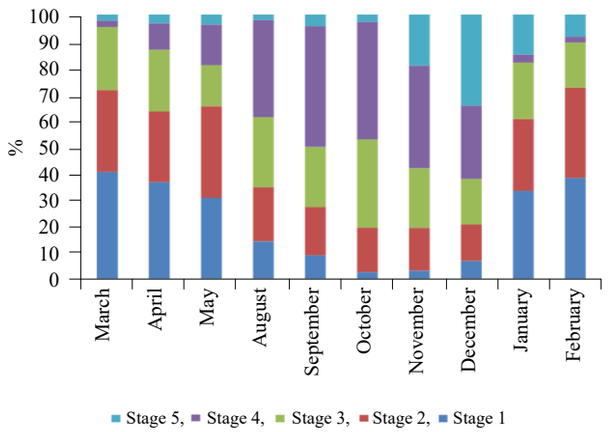

Fig. 4. Monthly variation in maturity stages of females

significantly ($p<0.05$) despite their ranges showing overlap. Stage IV ova displayed two modal values of 1.38 and 1.58 mm. The length at first maturity for females of *A. djedaba* from Ratnagiri coast was estimated to be 149 mm total length (Fig. 5).

Discussion

Length-weight relationship and morphometrics

The estimated 'b' values indicated isometric growth in males, females, indeterminates and pooled individuals. All r^2 values were >0.90 indicating a strong effect of size or influence of the length on the weight in all groups. Therefore, in the present study a generalised length-weight relationship equation for total individuals was given by $W = 0.1540\ L^{2.9341}$. Many researchers have carried out studies on length-weight relationship of this species. *A. djedaba* showed difference in the slope to earlier reports (Sivakami, 1990; Reuben *et al.,* 1992; Raje, 1993). Shuaib and Ayub (2011) reported negative allometry in males and isometry in females of *A. djedaba* from Karachi. Sajana and Bijoy (2017) reported that *A. djedaba* from Cochin coast exhibits isometric growth based on estimated b values. Negative allometry has also been reported by Taskavak and Biterceoglu (2001) from the coast of Turkey; Osman and Al Abdulhadi (2011) from the Arabian Gulf and Siwat *et al.* (2016) from Semerang waters. Negative allometry suggests that either the large specimens have changed body shape, *i.e.,* become more elongated or smaller specimens were in better nutritional condition at the time of sampling (Froese, 2006). The b values in the present study are found to be in the expected range of 2.5 to 3.5 (Froese, 2006). Variations in length-weight relationship can be attributed to several factors such as sex, gonad maturity, fullness of stomach, sample size, size range covered and habitat (Krishnamoorthi, 1971; Froese, 2006; Kende *et al.,* 2016).

In the present study, fork length and standard length showed highest correlation while lowest correlation was observed in anal height (0.7013) and snout length (0.7396). The strength and patterns of correlation were as expected for linear measurements. Further, the results were comparable to the previous study of the species by Sajana and Bijoy (2017) from Cochin. The morphometric indices obtained would be helpful for differentiating the sexes (Jardas *et al.,* 2004), for delineating sub-populations (Bektas and Beldus, 2009) and for analysing bilateral asymmetry (Jawad *et al.,* 2010).

Condition factor (K_n)

In the present study, the condition factor showed an increasing trend during the spawning season from August to November and thereafter showed a declining trend. Sivakami (1990) reported that condition factor followed a similar trend in both sexes and increasing

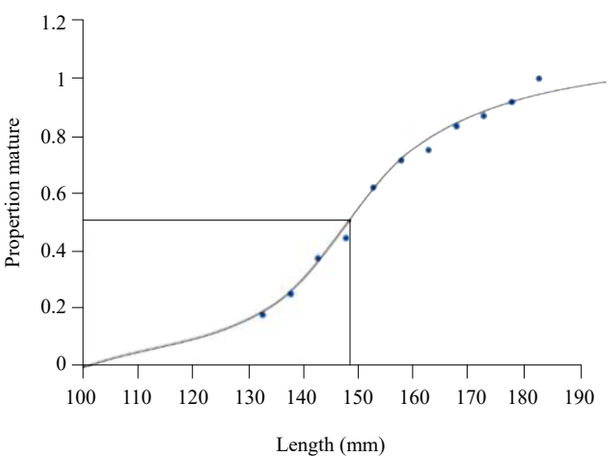

Fig. 5. Length at sexual maturity of *A. djedaba*

values corresponded with the spawning cycle. Further the values were closely correlated with the spawning cycle and to a lesser extent with the feeding activity. Raje (1993) observed that the relative condition factor in *A. djedaba* was associated with maturation of gonads and indicated a better health condition for the species. Similar observations were reported by Venkatramani and Natarajan (1984) and Osman and Al Abdulhadi (2011). Alterations in the general condition of fish can be due changes in gonad cycle and state of fullness of the alimentary canal (Weatherly, 1979). The K_n value is influenced by various factors like feeding intensity, food type, amount of fat or muscular development, age, sex and development stage of gonads of fish (Abowei, 2010).

Food and feeding biology

Table 3 gives a comparative account on the feeding habits of *A. djedaba* reported by different authors. The carnivorous feeding habit of *A. djedaba* from Ratnagiri coast is in conformation with the earlier studies conducted by Smith-Vaniz (1984), Sivakami (1990), Raje (1993) and Carpenter and Volker (2001). Carpenter and Volker (2001) stated that the fishes in the genus *Alepes* are all predators. However, variations in food items consumed by *A. djedaba* from different regions may be due to the dominance of respective food items in different regions. Juvenile and moderate sized individuals of *A. djedaba* were found to feed mainly on zooplankton dominated food items such as *Acetes* spp., copepods, shrimp larva and fish eggs whereas the bigger size individuals fed on juveniles of fishes. Food preference observed in individuals of different size groups can be attributed to size and availability of the prey organisms, mouth size and life history traits (Garcia *et al.,* 2018; Batool and Siddiqui, 2020). Earlier studies have suggested ontogenic variation in feeding preference of fish in this species (Labropoulou *et al.,* 1997; Garcia *et al.,* 2018; Batool and Siddiqui, 2020) *i.e.,* increase in body size results in increased demand of protein and fat contents which causes the fish to feed on large sized prey (Olson, 1996). The broad oral cavity and extensible stomach of these fishes facilitated feeding on large sized prey items (Batool and Siddiqui, 2020).

In the present study, most of the individuals were observed with empty stomach during spawning season and full stomachs during the month of March and April. It is well understood that most of the dietary energy is diverted for gonadal maturation leading to increased feeding. Similarly, reduced feeding is observed to cope up with the spawning stress. The results agree with the observations made by Sivakami (1990) and Osman and Al Abdulhadi (2011) for *A. djedaba.* Reduced feeding intensity in fishes during spawning season has also been reported by several authors (Bhalekar *et al.,* 2016; Borah *et al.,* 2016; Gurjar *et al.,* 2017; Sawant *et al.,* 2017).

Reproductive biology

In the present study, males were slightly dominant in population and significant difference ($p<0.05$) was noted in the sex ratio during a few months of the study period. The results conformed to the findings of Sivakami (1990) and Raje (1993). However, no significant deviation in the sex ratio was noted by Shuaib and Ayub (2011) and Siwat *et al.* (2016). Osman and Al Abdulhadi (2011) reported

Table 3. Food composition of *A. djedaba* from different localities

Locality	Main food items	Feeding habit	Author
Western Indian Ocean	Invertebrates, shrimps, copepods and larvae of decapod crustaceans	Carnivorous	Smith-Vaniz (1984)
Cochin	Fish juveniles (*Cynoglossus* spp., *Stolephorus* spp., *Leiognathus* spp.), ostracods (*Conchoecio* spp.), decapods (*Acetes* spp.), *Lucifer* spp., amphipods, cladocerans (*Evadna* sp.) and stomatopods	Carnivorous	Sivakami (1990)
Gujarat	*Acetes* spp., copepods, fish, *Myctophum* spp. and *Squilla* spp.	Carnivorous	Raje (1993)
East Indies	Shrimps, copepods, decapod larvae, other crustacean larvae and small fish	Carnivorous	Allen and Erdaman (2012)
Ratnagiri	*Acetes* spp., small fishes, copepods, shrimp larvae, fish scales, fish eggs, small crustacean and polychaetes	Carnivorous	Present study

Table 4. Observations on ova-diameter of *A. djedaba*

Stage		Average % of females in different maturity stages	Ova diameter (mm)	No of modes	Modal value (mm)
Immature	I	21.58	0.02 - 0.42	one	0.06
Developing	II	23.87	0.20 - 0.78	one	0.46
Maturing	III	22.31	0.58 - 1.24	one	0.88
Ripe	IV	22.60	1.10 - 2.32	two	1.38, 1.58
Spent	V	09.64	1.38 - 1.86 one		1.62

a predominance of females from the Arabian Gulf in *A. djedaba.* The change in the normal Mendelian ratio of 1:1 sex ratio can be attributed to partial segregation of mature forms through habitat preferences (Reynolds, 1974) due to migration (Collignon, 1960) or behavioural differences between sexes (Polonsky and Tormosova, 1969) rendering one sex to be more easily caught than the other.

Based on both the maturity stages and the GSI data, the spawning season of *A. djedaba,* appears to be from August to December along the Ratnagiri coast. Qasim (1973) has recorded the spawning season of the species to span the monsoon and post-monsoon months along the west coast of India. Sivakami (1990) reported the occurrence of spawners of *A. djedaba* during July to October from Cochin waters indicating a prolonged breeding season. Based on the recruitment patterns of the species, pronounced spawning has been noted in December followed by a less pronounced spawning in September (Reuben *et al.,* 1992). Several authors have pointed to prolonged spawning in the species (Raje, 1993; Kasim, 2003; Osman and Al Abdulhadi, 2011). In Karachi, Pakistan, spawners of *A. djedaba* are encountered almost throughout the year with two peaks from March to April and from August to December (Shuaib and Ayub, 2011). Maturity of *A. djedaba* from Semarang, Indonesia, has been noted during April to June (Siwat et al., 2016). In the present study, females in their advanced stages of maturity were encountered from the months of August to December and high GSI values were also found to coincide with these months. Therefore, it can be concluded that *A. djedaba* from Ratnagiri coast too has a protracted spawning season extending from August to December. Earlier reports on the GSI periodicity differ remarkably from the current findings (*e.g.* Sivakami, 1990; Shuaib and Ayub, 2011; Osman and Al Abdulhadi, 2011; Siwat *et al.,* 2016). The observed differences in the spawning season of *A. djedaba* from different studies could be attributed to spatial, environmental and stock level differences.

Generally, fecundity is a key factor to determine the revival capability of a fish population (Ahamed *et al.,* 2018). In the present study, *A. djedaba* was found to be a moderately fecund fish with absolute fecundity ranging from 15004 to 640800 eggs. Raje (1993) reported that the fecundity of *A. djedaba* from Veraval ranged between 621000 and 806386 in various size groups. Positive correlation between the size of the female and the number of eggs produced was noted. Similar trends in fecundity were reported by Kagwade (1968) for *Caranx kalla.* Shuaib and Ayub (2011) reported that the fecundity of *A. djedaba* from Pakistan ranged between 8981 and 75075 eggs (average 26649.3±17747.4) and that fecundity was related to gonad weight. The fecundity varies from species to species and within a species from one region to another in accordance to the reproductive potential of the stocks (Gurjar *et al.,* 2018).

The occurrence of two modes in Stage IV ovaries is indicative of multiple spawning of *A. djedaba* along the Ratnagiri coast during a spawning season. Sivakami (1990) reported the presence of two modes of mature ova in Stage VI females and commented that these ovarian batches constituted more than half of the total intra-ovarian eggs. Subrahmanyam (1968) noted that the eggs of *A. kleinii* from the Madras coast are pelagic, spherical and transparent, measuring 0.58 to 0.61 mm in diameter.

In present study along the Ratnagiri coast, the females of *A. djedaba* attained first maturity at 149 mm total length. Length at first maturity reported by different workers (Sivakami, 1990; Carpenter and Volker 2001; Osman and Al Abdulhadi, 2011; Siwat *et al.,* 2016) for *A. djedaba* ranged between 103 to 189 mm. Differences in size at first maturity within a species points possibly to the presence of distinct stocks and environmental factors including availability of food.

This study provides vital information on length-weight relationship, morphometrics, feeding and reproductive biology of *A. djedaba* from the Ratnagiri, Central west coast of India. *A. djedaba* was found to be a moderately fecund fish with a spawning season from August to December in the study region. The size at first maturity reported in the present study (149 mm) can be treated as minimum legal size (Mohamed *et al.,* 2014) for *A. djedaba* from Ratnagiri waters, for sustainable utilisation of the resource. This study provides an insight baseline knowledge about the biology of *A. djedaba,* which will be helpful for sustaining the landings of this species and future fisheries research in the region.

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