



## Reproductive biology of the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1816) from the Mahout coast, Sultanate of Oman

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### ABSTRACT

A study on the reproductive biology of the Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816) was made from the Arabian Sea coast of Mahout, Oman for a period of two years from September 2007 to August 2009. Occurrence of spent gonads during September-October and January-February during 2007-08 and from December to April and August during 2008-09 indicated difference in spawning periodicity between the years. Individual fish appeared to spawn for the second time in a year. The monthly Kn values in both the sexes could not be related to spawning activity. The length at first maturity ( $L_m$ ) for males and females were estimated at 252 and 257 mm respectively. Females were dominant than males in the catches and the annual sex-ratios differed significantly. The fecundity of females varied between 64,024 and 151,844 eggs with an average fecundity of 98,273 eggs. As the estimated  $L_m$  of *R. kanagurta* is lower than the size at capture along the Mahout coast, there is no management concern at present.

Keywords: Arabian Sea, Maturity, Oman, Spawning, *Rastrelliger kanagurta*

### Introduction

The Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1816) has wide distribution in the tropical Indo-west Pacific region forming one of the commercially important fisheries in several countries bordering the Red Sea, Oman Sea, Arabian Gulf and Pakistan, India, Sri Lanka, Bangladesh, Myanmar, Thailand and Malaysia (Fischer and Whitehead, 1974; Collette and Nauen, 1983; Fischer and Bianchi, 1984). Several studies on the biology and stock assessment of Indian mackerel from various coasts are available (Radhakrishnan, 1962; Rao, 1967; Sousa and Gislason, 1985; Gopakumar *et al.*, 1991; Noble *et al.*, 1992; Yohannan and Abdurahiman, 1998a, b; Rohit and Gupta, 2004; Moazzam *et al.*, 2005; Abdussamad *et al.*, 2010).

In Omani waters, the Indian mackerel is common (Randall, 1995) and the resource is harvested by the artisanal fishers using the gears such as gillnets and seines (Al-Abdessalaam, 1995). The estimated landings of this fish increased from 1,994 t in 1998 to 10,124 t in 2009 (GoSO, 2009). About five-fold increase in the catches in recent years has clearly indicated that the fishery appears as an emerging resource in the country. Other than the report of Jayabalan *et al.* (2014) on the age and growth of the Indian mackerel from the Sohar coast of Oman, no other published account is available on the biological

characteristics of the species from the Omani waters. Therefore, the present study was undertaken during 2007-2009 to understand the reproductive aspects of the species from the coast of Mahout in Oman bordering the Arabian Sea. The results obtained would help to plan for sustainable harvest of the Indian mackerel from the Omani waters.

### Materials and methods

A total of 1,357 numbers of mackerel were collected randomly from seines, gillnets and castnets from Mahout (Fig. 1) on monthly basis between September 2007 and August 2009. Due to inclement weather, no sample was available during December, June and August in 2007-08 and during October in 2008-09. The fish samples were brought to the laboratory in ice box. After washing, the total length (TL) of each fish was measured to the nearest 1 mm using a measuring board and the total wet weight (TW) was recorded to the nearest 1 g using an electronic balance. The fish was then dissected to determine the sex and maturity stage. Then the gonads were removed and weighed to the nearest 0.001 g using an electronic balance. Ovaries were preserved in 5% neutral formalin for subsequent ova-diameter and fecundity studies.

#### Maturity stages

The gonadal maturity key suggested by Pradhan and Palekar (1956) for *R. kanagurta* was considered

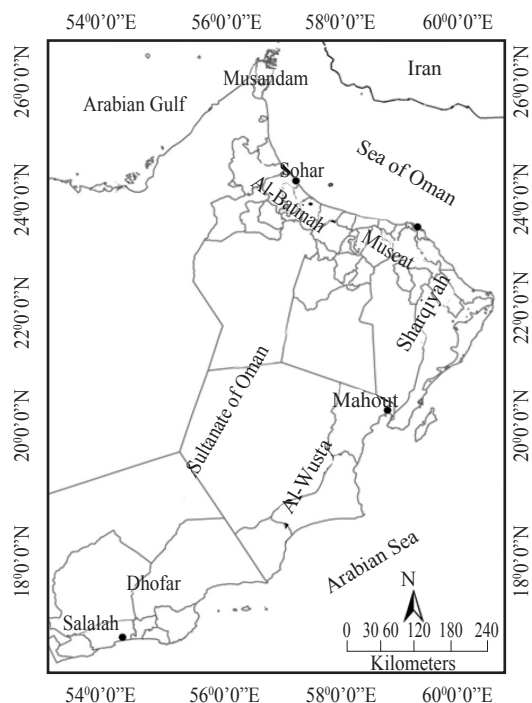


Fig. 1. Map showing different coastal regions and sampling locations

with slight modification. Seven stages of maturity both in females and males were established based on the macroscopic appearance of the gonads and extent they occupied the body cavity and also based on the microscopic structure of the ova (Table 1).

#### *Development of ova to maturity*

To trace the development of ova from immature to mature stage, 35 ovaries in different maturity stages (stages I-VII except stage VI) were used. The diameters of the ova were measured using an ocular micrometer fitted to the microscope as suggested in earlier studies (Prabhu, 1956; Jayabalan, 1986). One ocular micrometer division (m.d.) was equal to 13  $\mu\text{m}$ . Except in stages I and II, immature ova of less than 6 m.d. were not measured, as they represented the general egg stock. Pooled ova diameters from same stage of ovaries were grouped into 3 m.d. class intervals for percentage frequency curves.

#### *Length at first maturity*

The length at first maturity ( $L_m$ ) was calculated from pooled fish collected during 2007-08 and 2008-09 and grouped sex-wise into 1 cm size groups. The gonads

Table 1. Classification of maturity stages in *Rastrelliger kanagurta* from Omani waters

Stage of maturity	Male	Female		Position of last mode and maximum diameter of ova (in parentheses) in m.d. *(1 m.d. = 0.013mm)
	Nature and extent of testis in body cavity	Nature and extent of ovary in body cavity	Appearance of ova under microscope	
I Immature	Small, transparent, occupying up to 1/2 of body cavity	Small, transparent, occupying about 1/2 of body cavity, ova not visible to naked eye	Irregular, small, yolkless, transparent with clearly visible nucleus	1-3 (9)
II Maturing 1	Whitish, translucent, occupying more than 1/2 of body cavity	Yellow, cylindrical, ova not visible to naked eye, occupying above 1/2 of body cavity	Irregular, small, yolk deposit just started, transparent with clearly visible/partially visible nucleus	10-12 (18)
III Maturing 2	Whitish, occupying about 2/3 of body cavity	Pale yellow, granular ova visible to naked eye, occupying about 2/3 of body cavity	Ova with fair amount of yolk, assume round shape	16-18 (24)
IV Maturing 3	Creamy white, thick, occupy 3/4 of body cavity	Pinkish yellowish, ova clearly visible, occupy 3/4 of body cavity	Large sized ova, opaque, fully yolked	28-30 (39)
V Mature	Creamy white, soft, occupying full length of body cavity, under pressure milt oozes out	Deep yellowish, occupying full length of body cavity, large ova oozes out under slight pressure	Large sized, mature, transparent at periphery	43-45 (54)
VI Ripe/Running	Not encountered	Not encountered	---	---
VII Spent	Shrunken, little reddish, occupy about 1/2 of body cavity	Shrunken, reddish, wall loose, occupy about 1/2 of body cavity	Medium sized ova present with disintegrating mature ova; however few larger sized ova were intact	28-30

m.d.\* = Ocular micrometer division

in maturity stages III and above were considered as mature. Length at 50% maturity was calculated from the cumulative maturity percentage curve plotted against different lengths.

#### *Spawning season*

To determine the spawning season of the species, percentage occurrence of different maturity stages of gonads during various months was calculated and plotted.

#### *Gonado-somatic Index*

The monthly gonado-somatic index (GSI) for males and females was calculated using the formula:

$$GSI = GW/TW \times 100$$

where, *GW* is the gonad weight (g) and *TW*, the total body weight (g).

The monthly average surface water temperature (SST) in the region was related to the monthly GSI of the fish to indicate the influence of SST on gonad development in fish and the SST data for the study period were obtained from the Marine Ecology Section of the Marine Science and Fisheries Centre.

#### *Relative condition factor (Kn)*

To understand the general well-being of the fish, the monthly *Kn* was estimated by pooling the data of 2007-08 and 2008-09 adapting the formula of Le Cren (1951) as:

$$Kn = TW/aL^b$$

where *TW* = observed weight (g), *aL<sup>b</sup>* = calculated weight obtained from the length-weight relationship.

#### *Fecundity*

The fecundity of females was estimated gravimetrically from 22 ovaries in stage V. A small piece of the ovary was removed and weighed to the nearest 0.001g. The piece of ovary was then preserved in 'modified Gilson's fluid' (Bagenal and Brawn, 1971) for a week. Later, the piece of ovary was transferred to a counting chamber and all the mature eggs were counted under a binocular microscope. From the number of mature ova in the piece, the total number of mature ova for the whole ovary was estimated as:

$$Fecundity = (Total\ weight\ of\ the\ ovary) / (Weight\ of\ the\ sample) * Number\ of\ mature\ ova\ in\ the\ sample$$

The relationship between the fecundity and total length, body weight and ovary weight was found out by the least square method as:

$$F = aX^b$$

where, *F* = fecundity, *a* = constant, *X* = variable (fish length, fish weight or ovary weight) and *b* = correlation coefficient.

#### *Sex ratio*

The monthly sex-ratio of fish in the commercial catches was estimated as male to female ratio. Both the monthly and annual sex-ratios were tested for the expected ratio of 1:1 by the technique of chi-square( $\chi^2$ ) analysis.

## **Results and discussion**

### *Development of intra-ovarian eggs to maturity and spawning*

Fig. 2 depicts the development of immature egg to mature stage through different stages of ovaries. In stage I ovary, nearly 76% of immature ova measured up to 3 m.d. and few larger ova measured up to 9 m.d. This immature group of ova represents the general egg stock in the ovary. From this group of eggs, a batch of eggs developed from immature to mature stage. This batch of developing ova has a mode at 10-12 m.d. in stage II, 16-18 m.d. in stage III, 28-30 m.d. in stage IV and 43-45 m.d. in stage V ovaries. The mode at 16-18 m.d. was stationary in stages IV to VII. However, in stage VII ovary, there were modes at 16-18 m.d., 28-30 m.d. and a less prominent mode of ova at 40-42 m.d.

In mature ovary (stage V), two modes of maturing and two modes of mature groups of ova were present. The modes of mature groups of ova (37-39 m.d. and 43-45 m.d.) were not clearly separated from each other. In ovary of stage VII, besides few disintegrating larger ova, a group of mature eggs forming a minor mode at 40-42 m.d. were present. These eggs in this mode may have spawned in the same spawning season. Hence, it appears that the fish might release the eggs in batches during spawning along the Mahout coast. Further, the presence of intermediate groups of maturing eggs indicates that the fish may spawn for the second time in a year. This observation is in agreement with the earlier studies from Indian waters where there was a possibility for second spawning in the same season (Sekharan, 1958; Rao, 1967). However, Yohannan and Abdurahiman (1998b) observed the mature ovary of *R. kanagurta* to possess six batches of eggs and hence, was presumed that the fish is an intermittent spawner and always utilises favourable environment for spawning (Yohannan and Abdurahiman, 1998b).

#### *Spawning*

##### *Gonado-somatic index*

During 2007-08, higher values of GSI in males and females were recorded during March-May and September (Fig. 3). During most of the months, GSI values were

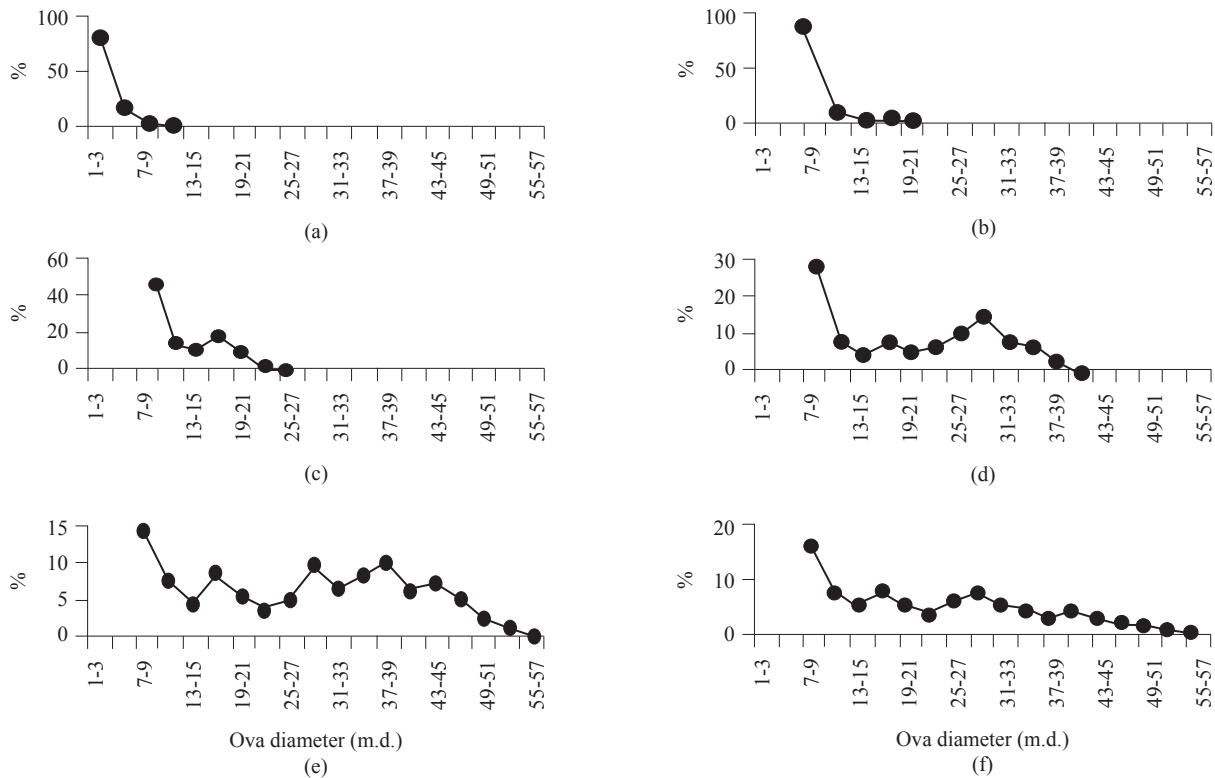


Fig. 2. Development of ova to maturity in *R. kanagurta* through different stages of ovary. (a) Stage I, (b) Stage II, (c) Stage III, (d) Stage IV, (e) Stage V, (f) Stage VI

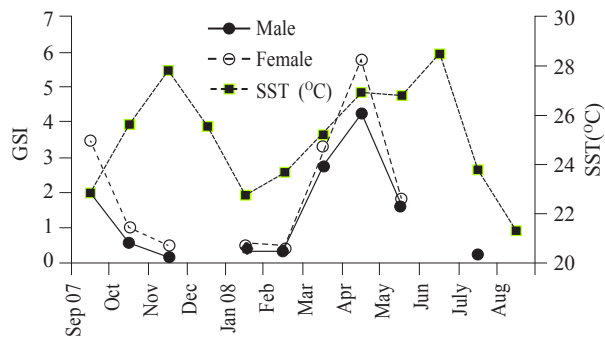


Fig. 3. Relationship between average monthly SST and GSI in *R. kanagurta* in Mahout during 2007-08

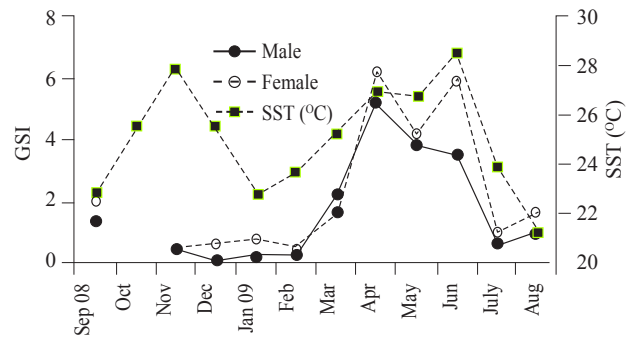


Fig. 4. Relationship between average monthly SST and GSI in *R. kanagurta* in Mahout during 2008-09

lower than the weighted average in males (1.38) and females (1.90). The lowest and highest monthly SST in Mahout were recorded during August (21.3°C) and June (28.5°C) respectively. While, GSI values from March-May increased with increase of temperature during the above months, the trend was not clear for other months.

The lowest monthly GSI during 2008-09 was recorded in December in males (0.1209) and in November in females (0.4612) (Fig. 4). The GSI started to increase from December to April in males and from February to April in females. In males, a clear trend in the increase of

GSI was observed in relation to increase in SST during the same period.

*Relative condition factor (Kn)*

Though, an increasing trend in the monthly *Kn* values was observed in males and females from October (Fig. 5), there was a drop in the values during March. Thereafter, an irregular trend was noticed. Except in March, the *Kn* values during other months in both the sexes fluctuated. Hence, it was not possible to relate them to spawning activity. This may be due to the higher feeding intensity of the fish.

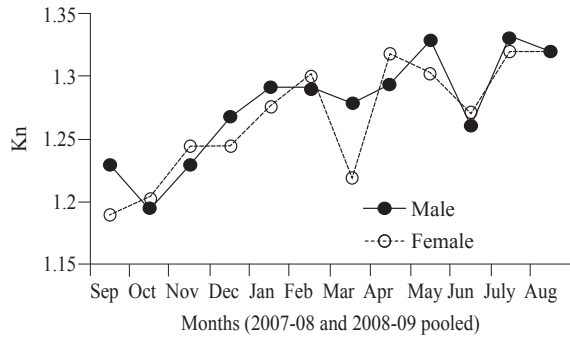


Fig. 5. Monthly Kn in *R. kanagurta* in Mahout during 2007-2009

*Spawning season*

Observation of different stages of gonads in Mahout during 2007-08 (Fig. 6) and 2008-09 (Fig. 7) indicated the presence of mature gonads (stage V) almost throughout the year. The spent gonads occurred during September-October and January-February during 2007-08 and from December-April and August during 2008-09. Hence, it appears that the spawning period is restricted to 4-6 months in Mahout.

Variations in periodicities of spawning of Indian mackerel have been observed in Indian waters (Chidambaram *et al.*, 1952; Radhakrishnan, 1962; Sekharan, 1958; Rao, 1967; Gopakumar *et al.*, 1991; Yohannan and Abdurahiman, 1998b) where the gravid fish occur almost throughout the year (Rohit and Gupta, 2004). Indian mackerel is a prolific breeder and always utilises favourable environment especially

suitable temperature and availability of food for spawning (Yohannan and Abdurahiman, 1998a). The variations observed in the spawning periods during the present study at Mahout, could be attributed to the environmental variations over the years.

*Length at first maturity ( $L_m$ )*

All fish measuring less than 121 mm were immature. Males matured slightly at a lower length than females. The 50% maturity was calculated at 252 mm in males and 257 mm in females (Fig. 8). The estimates of  $L_m$  of Indian mackerel differ in various studies. Along the Arabian Sea coasts of India, the average  $L_m$  of *R. kanagurta* varied from 180 to 223 mm (Sekharan, 1958; Rao, 1967; Gopakumar *et al.*, 1991; Yohannan and Abdurahiman, 1998b; Rohit and Gupta, 2004) and in the Bay of Bengal coast, the  $L_m$  was estimated between 182.4 and 188 mm (Abdussamad *et al.*, 2006; 2010). From Seychelles, the  $L_m$  of Indian mackerel was estimated at 205 mm (Sousa and Gislason, 1985). In the present study, the estimated  $L_m$  of *R. kanagurta* is higher than from other coasts. Hence, a comparative genetic analysis of the species from various coasts of its distribution would indicate whether the Indian mackerel fishery is supported by a single stock or by more than one stock.

*Sex ratio*

Females were dominant in the catches during most part of the year including the spawning months. The annual male to female ratio was 1: 1.57 during 2007-08

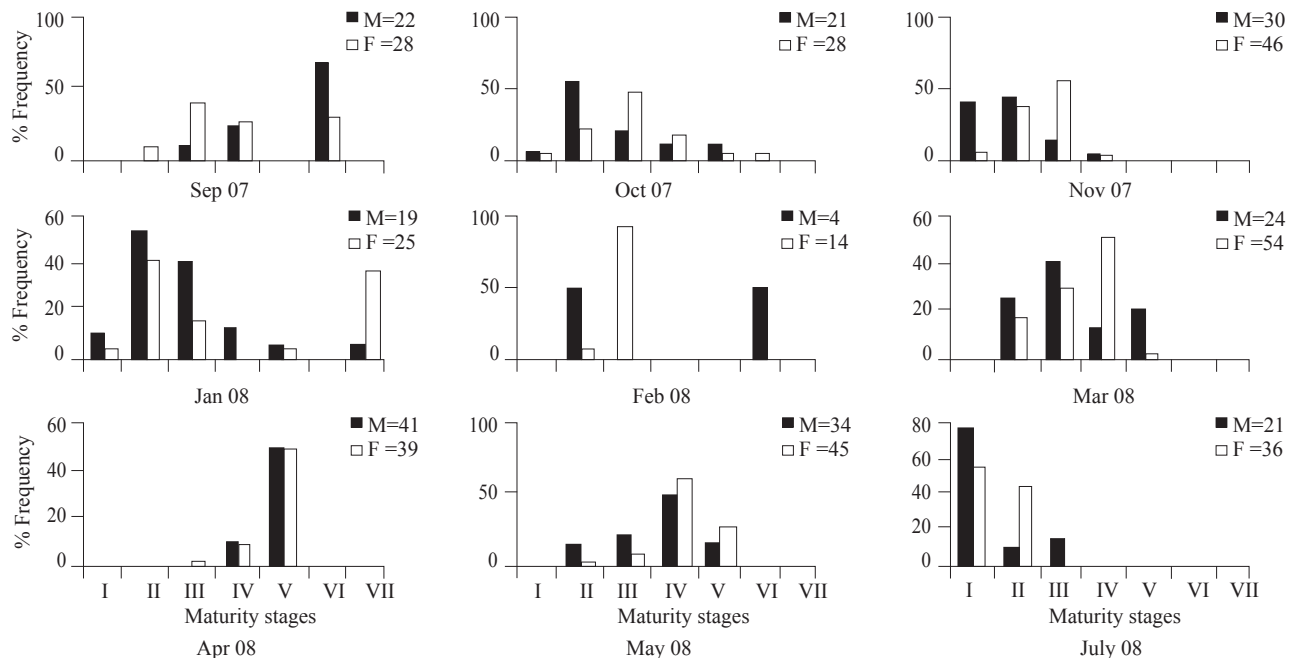


Fig. 6. Monthly maturity stages of *R. kanagurta* in Mahout during 2007-08

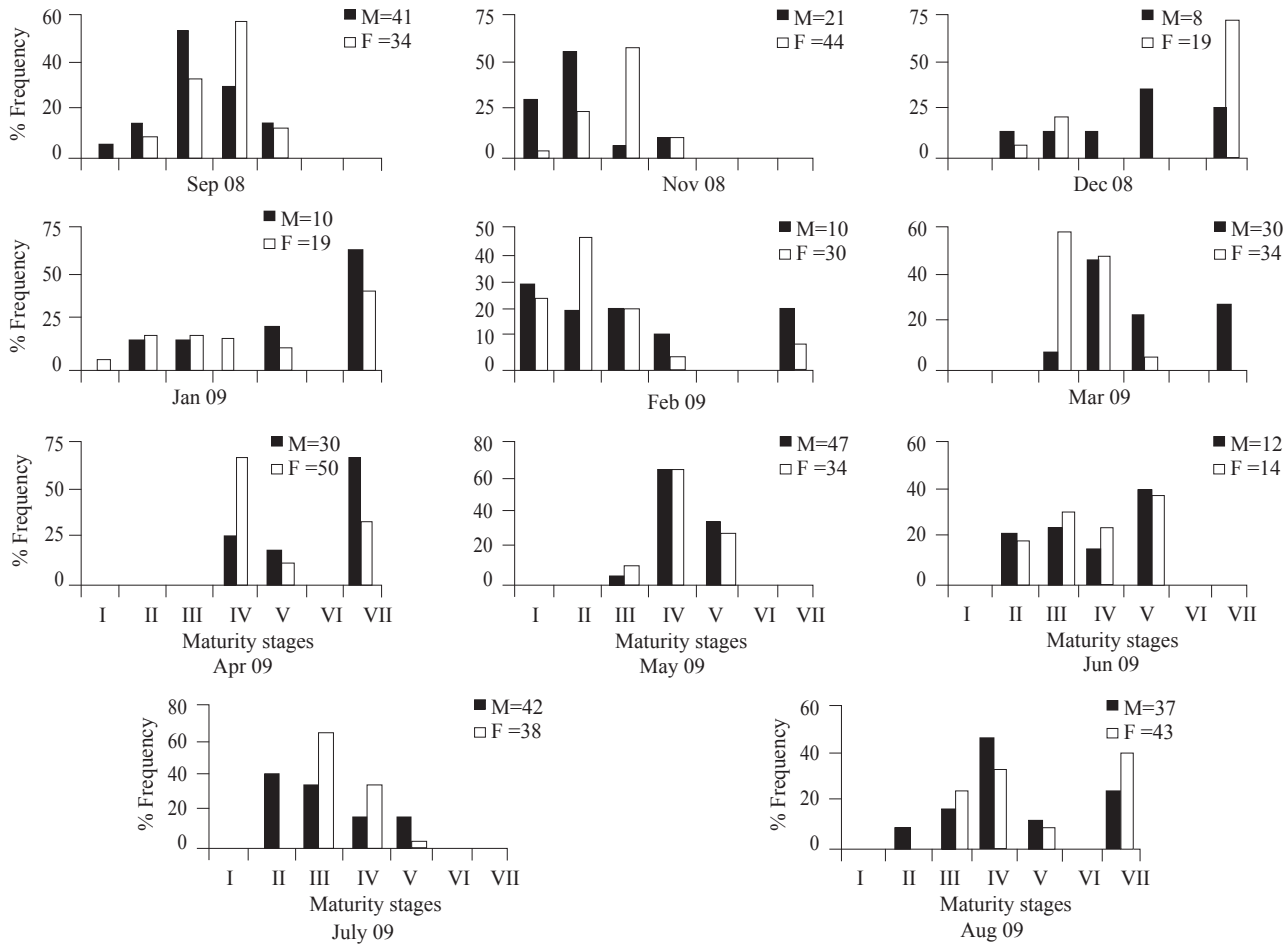


Fig. 7. Distribution of maturity stages of gonads in *R. kanagurta* in Mahout during 2008-09

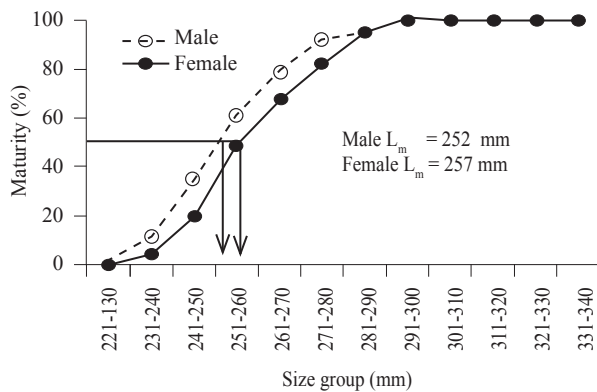


Fig. 8. Length at first maturity of *R. kanagurta* in Mahout

(Table 2) and 1: 1.29 during 2008-09 (Table 3). While, the annual sex ratio differed significantly during both the years, the monthly sex ratios significantly differed during few months. The overall sex ratio indicated heterogeneous distribution among males and females of *R. kanagurta* in Mahout. While the sex ratio was found to be almost close to 1:1 from the Pakistan coast (Moazzam *et al.*, 2005),

Table 2. Monthly sex ratio in *R. kanagurta* in Mahout during 2007-08

Month	Male	Female	M: F	$\chi^2$ value	p-value
Sep 07	22	28	1: 1.27	0.72	0.396
Oct	21	53	1: 2.52	13.838*	0.000199
Nov	30	46	1: 1.53	3.368	0.066
Dec	No data				
Jan 08	19	25	1: 1.32	0.8181	0.3657
Feb	4	16	1: 4	7.2*	0.00729
Mar	24	54	1: 2.25	11.538*	0.0006817
Apr	41	37	1: 0.9	0.205	0.6506
May	34	45	1: 1.32	1.53	0.21586
Jun	No data				
July	21	36	1: 1.71	3.947*	0.0469
Aug	No data				
Total	216	340	1: 1.57	27.655*	1.45021E-07

\*Significant at 5% level

along the Indian coasts both homogeneous (Gopakumar *et al.*, 1991) and heterogeneous distribution of sexes with dominance of males (Rohit *et al.*, 1998) were reported.

Table 3. Monthly sex ratio in *R. kanagurta* in Mahout during 2008-09

Month	Male	Female	M: F	$\chi^2$ value	p-value
Sep 08	41	34	1:0.83	0.653	0.4189
Oct	No data				
Nov	21	44	1:2.1	8.138*	0.00433
Dec	8	19	1: 2.38	4.48148*	0.034
Jan 09	10	32	1:3.2	11.523*	0.000687
Feb	10	30	1:3	10.00*	0.001565
Mar	30	35	1:1.17	0.384	0.535
Apr	30	50	1:1.67	5.00*	0.0253
May	47	33	1:0.7	2.45	0.1175
Jun	12	14	1:1.17	0.1538	0.694
July	42	38	1:0.9	0.20	0.654
Aug	37	43	1:1.16	0.45	0.502
Total	288	372	1:1.29	10.6909*	0.00107

\*Significant at 5% level

**Fecundity**

The fecundity of *R. kanagurta* in Mahout varied between 64,024 and 151,844 eggs with an average fecundity of 98,273 eggs (Table 4). The minimum fecundity was recorded in a female fish with 27.5 cm TL, 302 g body weight and 9.61 g of ovary weight. The highest fecundity was from a fish measuring 31.5 cm TL, 476 g of total weight and 34.22 g ovary weight.

The relationship of fecundity (F) and total length of fish (TL) (Fig. 9a) was estimated as:

$$F = 9896.4 \text{ TL} - 195290 \text{ (R}^2 = 0.6043\text{)}$$

The relationship between fecundity (F) and total weight of fish (TW) (Fig. 9b) was found to be:

$$F = 304.53 \text{ TW} - 4368.1 \text{ (R}^2 = 0.6936\text{)}$$

The relationship between the fecundity (F) and ovary weight (OW) (Fig. 9c) was calculated as:

$$F = 2748.4 \text{ OW} + 44832 \text{ (R}^2 = 0.7651\text{)}$$

Among the different relationships calculated, the R<sup>2</sup> values indicated better correlation between the fecundity

Table 4. Fecundity of *R. kanagurta* in Mahout

Total length (cm)	Total weight (g)	Ovary weight (g)	Fecundity
27	262	12.73	81,744
27.2	276	13.78	78,936
27.5	286	19.34	90,948
27.5	302	9.61	64,024
28	262	11.42	77,290
28.1	290	17.2	71,630
28.3	272	13.72	94,112
28.5	312	17.02	92,352
28.7	312	11.75	66,768
29	302	17.14	89,090
29.4	298	15.36	92,976
29.6	302	22.75	107,278
30	322	19.57	85,974
30.1	342	23.41	108,072
30.2	340	12.52	81,940
31	370	17.92	119,880
31.3	416	21.38	127,259
31.5	476	34.22	151,844
32	403	32.19	137,826
32.2	386	19.28	98,044
32.5	464	33.79	123,888
33	420	31.68	120,120

and ovary weight than the total length and total weight of fish. The fecundity estimates in the present study are higher than those obtained from the coasts of India, where various authors have indicated different levels of fecundity ranging from 20,911 to 123,000 ova per individual (Devanesan and John, 1940; Rao, 1967; Gopakumar *et al.*, 1991; Abdussamad *et al.*, 2010). Along the Mahout coast, during the period of the study, the size of *R. kanagurta* in commercial landings ranged from 161 to 350 mm TL and the average length at capture (L<sub>c</sub>) was estimated at 280 mm TL (Zaki *et al.*, 2011). As the estimated L<sub>m</sub> of both males (252 mm) and females (257 mm) in the present study were lower than the L<sub>c</sub>, it may be concluded that the fishery is operating at satisfactory level and no regulatory measures are needed at present along the Mahout coast.

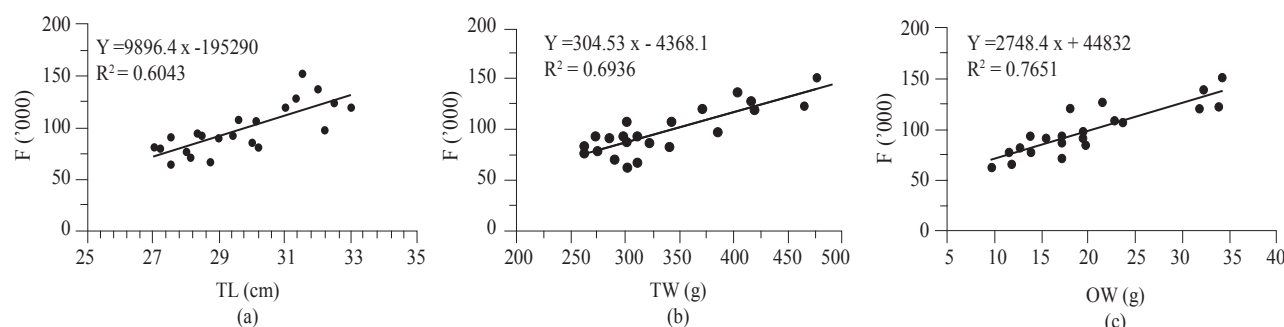


Fig. 9. Relationship between fecundity and (a) total length (TL), (b) total weight (TW) and (c) ovary weight (OW) of *R. kanagurta* in Mahout

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