REPRODUCTIVE BIOLOGY OF INDIAN MACKEREL, *RASTRELLIGER KANAGURTA* (CUVIER, 1816) FROM COASTAL REGION, MYANMAR

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Abstract

The present study related to the reproductive biology of Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816) was conducted from January 2021 to December 2021. A total of 360 specimens of *Rastrelliger kanagurta* were collected randomly to study their length-weight relationship, sex ratio, gonadosomatic index (GSI), hepatosomatic index(HSI), fecundity and stages of gonad maturity. During the study period, the sex ratio of male to female was 1:1.02. Significant correlation existed between fish length and weight in males ($W = 0.0277L^{3.2159}$, $R^2 = 0.7455$) and females ($W = 0.0293\ L^{3.7046}$, $R^2 = 0.7652$). The highest GSI values of male and female were found in May, August, October and December, 2021. The lowest GSI values of male and female were observed in January and June, 2021. The highest value of HSI was found in March, 2021 whereas the lowest HSI value was in October, 2021 in both sexes. The GSI and HSI values were inversely correlated. Two reproductive cycles in male and female were observed with similar reproductive development. The fecundity of females varied between 2300 eggs and 78000 eggs. Total length, body weight and ovary weight were in linear relationship with fecundity. Macroscopic observation based on the appearance of the sample gonads could be classified into six maturity stages; immature, maturing1, maturing2, mature, spawning and spent. Six developmental stages of oogenesis were classified based on the chromatin nucleolus, perinucleolar, cortical alveolar, vitellogenesis, maturation and ovulation conditions. Six developmental stages of spermatogenesis were found as primary and secondary spermatogonia, primary and secondary spermatocyte, spermatid and spermatozoa. Understanding the breeding season of *Rastrelliger kanagurta* is a crucial necessity in obtaining scientific knowledge on artificial propagation process.

Keyword Reproductive biology, Maturity stages, Rastrelliger kanagurta

Introduction

Fishes play an important role in healthy nutrition for humans' consumption. In Myanmar, the total production of fish and shell fish in 2016 was more than 100,000 tonnes (FAO, 2018). Among them, 47% are freshwater varieties and 53% from the sea. Marine aquaculture has been developed in Myanmar in Rakhine Coastal and Tanintharyi Coastal water. Aquaculture sector is interested in the species and culture in the coastal area of Myanmar.

Among the commercially important species, *Rastrelliger kanagurta* (Indian mackerel) is one of the valuable economic species in Myanmar. It is commonly known as Pa-Lar-Tue in local and it belongs to Scombridae family. This fish is valued for its highly nourishing quality and fish oil was extracted for use in food or pharmaceutical industry (Ferdosh, *et al.*, 2012). The flesh of *Rastrelliger kanagurta* was used for marketed fresh, frozen, canned, dried salted, and smoked products. The study of reproductive biology of fishes is essential for conservation and selecting fish candidates of aquaculture from the wild. Fish reproductive biology plays an important role for fishery management and sustainable aquaculture. Histological observation describes the progression of the gonadal development cycle for both males and females during reproductive season.

There are few reports on the reproductive aspects of *Rastrelliger kanagurta* in Myanmar. Research of reproductive biology of *Rastrelliger kanagurta* will enhance the artificial breeding of *Rastrelliger kanagurta* which has high market demand for export. Nowadays, fisheries sectors

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have been changed to sustainable aquaculture production. Information provided in the present research will be important knowledge for the aquaculture farmers who want to start *Rastrelliger kanagurta* culture in coastal area of Myanmar.

The present study was carried out for the reproductive biology based on the various aspects such as length-weight relationship, sex ratio, GSI, HSI, fecundity and analysed the different stages of ovary and testis through morphological and histological examination of *Rastrelliger kanagurta*.

Materials and Methods

Study period and collection sites

The study was conducted from January 2021 to December 2021. Fish samples were monthly obtained from Nyaungdan jetty, Pazundaung Township, Yangon Region, where the fishes were transported from Rakhine Coastal Region.

Sample Collection

A total of 360 Indian mackerels were collected during the study period. A total of 30 specimens in different sizes were sampled monthly. Fish were randomly chosen and samples were put in ice box and transported to the Laboratory of Fisheries and Aquaculture, University of Yangon. Total lengths and body weight were recorded individually. Gonad weight and liver weight were taken by an electronic balance of 0.001 g accuracy. Size, color and appearance of the gonads were noted.

Identification and classification

Identification and classification of *Rastrelliger kanagurta* (Cuvier, 1816) were based on Day (1878), Talwar and Jhingram (1992) and Fishbase (2013).

Length-weight relationship

Length-weight relationship for males and females were calculated using a formula,

$W = aL^b$ (Le Cren, 1951),

W = body weight of fish

L = total length of fish,

a = constant (intercept)

b = the length exponent (slope)

Sex ratio

All fishes were examined for monthly sex ratio using the following formula;

$$\text{Sex ratio} = \frac{\text{Total number of male}}{\text{Total number of female}}$$

Analysis of Gonadosomatic Index (GSI) (Agarwal, 1996)

Monthly conditions of ovaries were checked and recorded. Calculation of GSI was conducted in order to estimate the peak and decline of the breeding conditions.

Gonadosomatic Index (GSI) was calculated using the formula;

$$\text{GSI} = \frac{\text{Gonad weight}}{\text{Whole body weight}} \times 100$$

Analysis of Hepatosomatic Index (HSI) (Wingfield and Grimm, 1977)

$$\text{HSI} = \frac{\text{Weight of liver}}{\text{Whole body weight}} \times 100$$

Fecundity (Bagenal, 1978)

In the present study the fecundity of *R. kanagurta* was determined from the investigation of 30 fishes with a total length range of 18 - 30 cm. The gravimetric method was used and checked the ripe ovary for estimating fecundity. The ovary (1 g) was weighed and number of eggs was counted. The relationships of total length and fecundity, body weight and fecundity and ovary weight and fecundity were calculated.

$$\text{N} = \frac{\text{Wt} \times \text{Ns}}{\text{Ws}} \quad \text{(Bagenal, 1978)}$$

Where, Wt = Total weight of ovary; Ws = Weight of subsample;

Ns = Number of oocytes in the subsample

Maturity stages of gonads

Maturity stages were recorded based on gross morphology of gonads development. The characters used for the classification of the gonads were the appearance, color, size of the ovary (bulging, half shrink and the presence of blood vessels on the ovary). The macroscopic examination of the gonads could be classified as five stages of maturity which were categorized as immature, maturing, mature, spawning, spent in both males and females. Percentage of different stages was recorded from slides sections of ovaries.

Histological study of gonads

Gonad samples were taken for further histological examination by using double staining method according to Harris's Haematoxylin and Eosin methods. Gonad tissues were dehydrated with a series of Ethanol and cleared in xylene. They were embedded in paraffin and the fixed tissues were serially sectioned at 5µm thickness and stained with Haematoxylin and Eosin. They were then mounted in DPX.

The sectioned ovaries and testes were observed under the compound microscope (Olympus – CX131). Spermatogenesis could be classified into five stages involved the spermatogonia, primary and secondary spermatocyte, spermatid and spermatozoa. Five oocyte developmental stages of oogenesis were classified as chromatin nucleolus, perinucleolar, cortical alveolar, vitellogenesis, and maturation (Pradhan and Palekar, 1956; Ravaglia and Maggese, 2002; Agrawal, 2004).

Data analysis

Linear regression method was used to analyze the length-weight relationship of male and female, relationship between fecundity and body weight, total length and ovary weight of the female. The sex ratio was tested by using chi-square test.

Male

Female

Figure 1 Morphology of *Rastrelliger kanagurta*

Results

Monthly Length-weight variations of males and females of *Rastrelliger kanagurta*

The regression equations for the length-weight relationship of males and females were calculated using the data described in Table 1 and 2, however, undifferentiated individuals were excluded.

Table 1 Monthly variation in body parameters of male *Rastrelliger kanagurta*

Month	Male		
	Sample number	Total length(cm)	Body weight(g)
January	12	24.13± 2.13	158.78 ±49.29
February	14	22.5 ±2.29	132.34 ±44.44
March	13	25.07± 2.58	188.7±63.98
April	15	24.3 ±2.21	160.52 ±52.15
May	14	22.35 ±2.93	137.57± 58.48
June	16	23.59± 0.88	144 ±20.51
July	16	22.56 ±2.01	130.68 ±33.04
August	13	23.61 ±3.60	159.31 ±67.32
September	13	24.77 ±2.77	185.36 ±60.33
October	15	22.65 ±6.38	150.86 ±59.66
November	14	23.89± 0.73	158.65 ±13.27
December	12	24.91± 1.93	187.44 ±46.29

The total length (TL) of male ranged from 18.0cm to 30.0cm with a mean value of 23.81±2.48 cm. The body weight (BW) of male ranged from 68.3g to 296.9g with a mean value of 158.08±52.08g. The length-weight relation for male was $W = 0.0277L^{3.2159}$ (b=3.2159, $R^2 = 0.7455$, n=167) (Fig. 2).

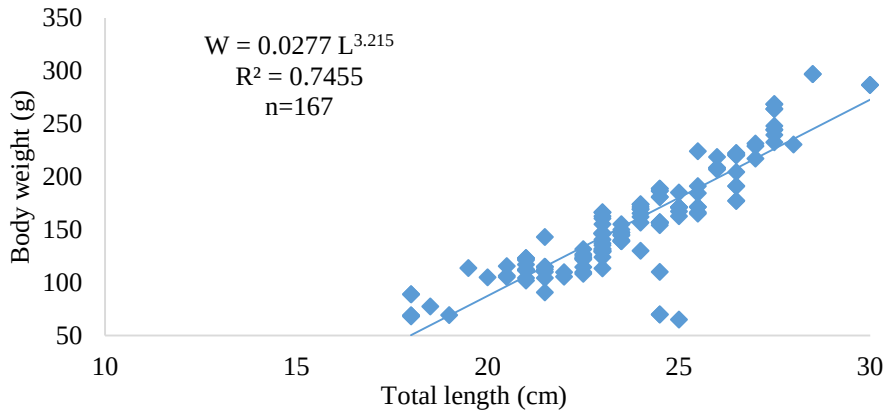


Figure 2 Length-weight relationship of male *Rastrelliger kanagurta*

Table 2 Monthly variations in body parameters of female *Rastrelliger kanagurta*

Month	Female		
	Sample number	Total length(cm)	Body weight(g)
January	15	23.43 ± 1.28	139.85 ± 32.67
February	13	22.42 ± 3.06	143.03 ± 58.12
March	17	23.94 ± 2.42	166.70 ± 59.23
April	13	23.07 ± 1.20	129.9 ± 28.67
May	16	24.71 ± 2.55	185.42 ± 47.40
June	11	23.72 ± 1.40	148.18 ± 24.50
July	13	21.96 ± 1.54	120.38 ± 24.34
August	17	22.06 ± 3.38	144.69 ± 69.68
September	17	23.76 ± 3.02	169.28 ± 55.10
October	15	23.8 ± 2.21	160.36 ± 45.78
November	16	24.18 ± 0.89	162.85 ± 10.53
December	16	23.97 ± 1.34	158.30 ± 43.04

The total length (TL) of female ranged from 18.0cm to 30.0cm with a mean value of 23.85± 2.45 cm during the studied period. The body weight (BW) of female ranged from 68.5g to 332.6g with a mean value of 160.88±52.43 g. The length-weight relation for female was $W = 0.0293\ L^{3.7046}$ (b=3.7046, $R^2 = 0.7652$, n=179) (Fig. 3).

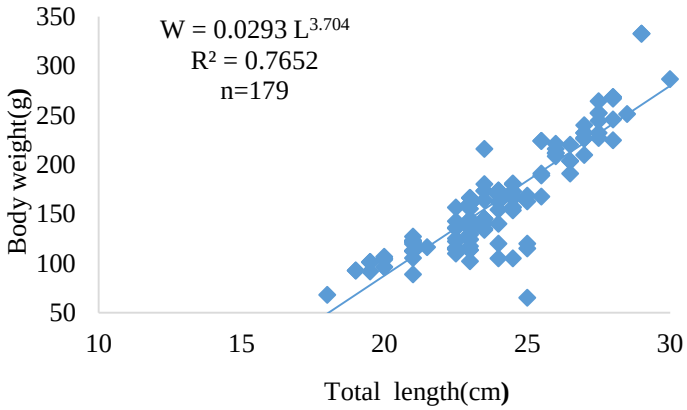


Figure 3 Length-weight relationship of female *Rastrelliger kanagurta*

Sex ratio of *Rastrelliger kanagurta*

The observed sex ratio was not different during the studied period. The percentages of the male and female populations were 49% and 51% respectively during the studied period. The overall sex ratio of male to female was approximately 1:1.The monthly distributions of the sex ratio were presented in Table 3. Monthly variation of sex ratio of fish was described in (Fig.4).

Table 3 Monthly variations of sex ratio of *Rastrelliger kanagurta*

Months	Total number	Number of male	Number of female	Undifferentiated number	Sex ratio (M:F)
January	30	12	15	3	0.8:1
February	30	14	13	3	1.08:1
March	30	15	11	4	1.36:1
April	30	15	13	2	1.15:1
May	30	15	15	0	1:1
June	30	16	11	3	1.45:1
July	30	15	14	1	1.07:1
August	30	13	17	0	0.76:1
September	30	13	15	2	0.86:1
October	30	14	16	0	0.87:1
November	30	14	16	0	0.87:1
December	30	12	16	2	0.75:1
Total	360	168	172	20	0.99:1

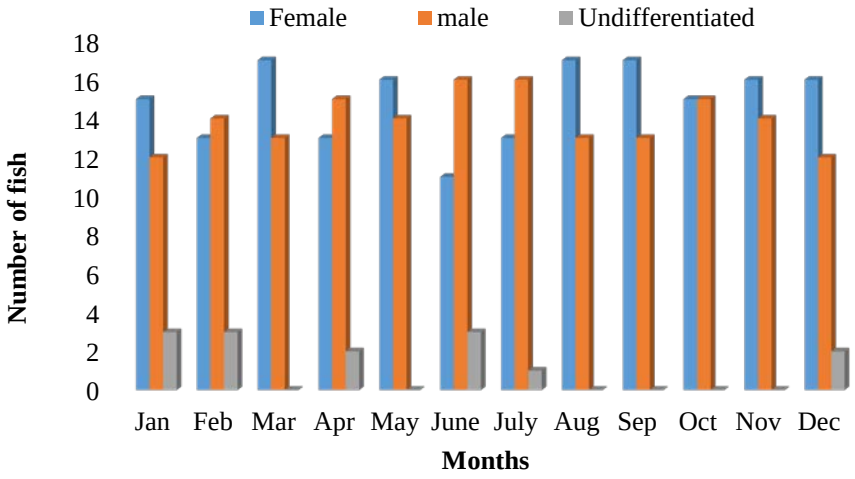


Figure 4 Monthly variation of sex ratio in *Rastrelliger kanagurta*

Fecundity of *Rastrelliger kanagurta*

In the present study, the 30 ripe females were evaluated for fecundity. The fecundity was correlated with the total length, body weight and ovary weight. The fecundity of *Rastrelliger kanagurta* was determined ranging from 18.0 to 30.0cm in total length and 68.5g to 332.6g in body weight. The fecundity of females varied between 2300 eggs and 78000 eggs (Table 4).

Table 4 Fecundity in ripe individuals of *Rastrelliger kanagurta*

Sample number	Total length(cm)	Body weight(g)	Ovary weight(g)	Number of mature ova (Fecundity)
1	18	68	2.6	2860
2	22.5	115.7	9.8	29400
3	24.5	172.6	7.3	25500
4	27	239.7	9.6	28650
5	28	224.7	8.3	27190
6	28	245.6	10.5	42000
7	21	119.7	5.9	13200
8	29	332.6	21.9	77600
9	26	221.2	6.7	15260
10	27	231.9	5.2	7800
11	27	226.3	3.6	2800
12	23.5	173.5	3.7	6510
13	26	215.8	4.7	5570
14	24.5	167.3	3.9	4960
15	28	266.6	29.2	52000
16	27.5	227.2	6.2	3360
17	23.5	134	4.8	2310
18	27.5	231.9	6.5	7680
19	24	169.6	4.9	5980
20	23	137.8	3	2700
21	25	65	3.2	3400
22	24.5	172.8	8.5	8680
23	26.5	203.6	9.3	5950
24	28	268.4	13.1	13500
25	27.5	252.2	11.3	9000
26	30	286.5	13.2	19300
27	23	160.5	4.5	6100
28	24.5	180.2	3.7	3500
29	24.5	167	5.1	3600
30	25.5	224	12.8	49700

The relationship between the fecundity (F) and total length (TL)

The relationship between fecundity (F) and total length of fish (TL) was calculated and the result was $F = 2891.6\ TL - 57486$ ($R^2 = 0.1652$). The relationship between fecundity and total length was found in linear form (Fig.5).

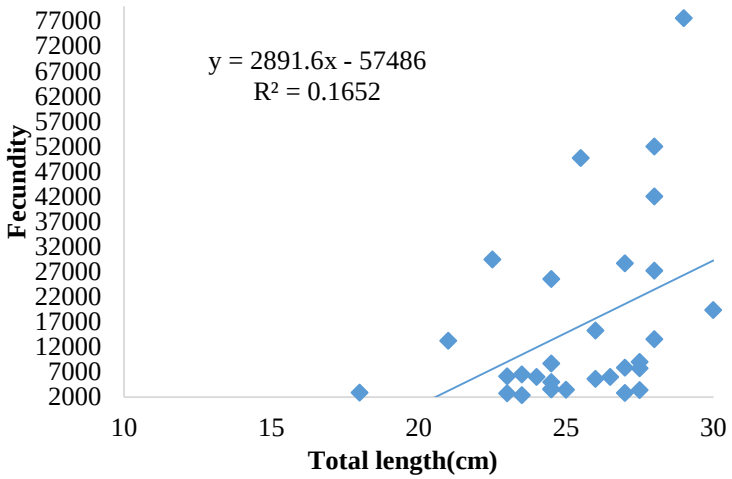


Figure 5 Total length and fecundity relationship of *Rastrelliger kanagurta*

The relationship between the fecundity (F) and body weight (BW)

The relationship between fecundity (F) and body weight of fish (BW) was calculated and it was F = 161.78 BW – 15626 (R^2 = 0.2981). The linear relationship between fecundity and fish weight showed that the fecundity increased in direct proportional to fish weight (Fig. 6).

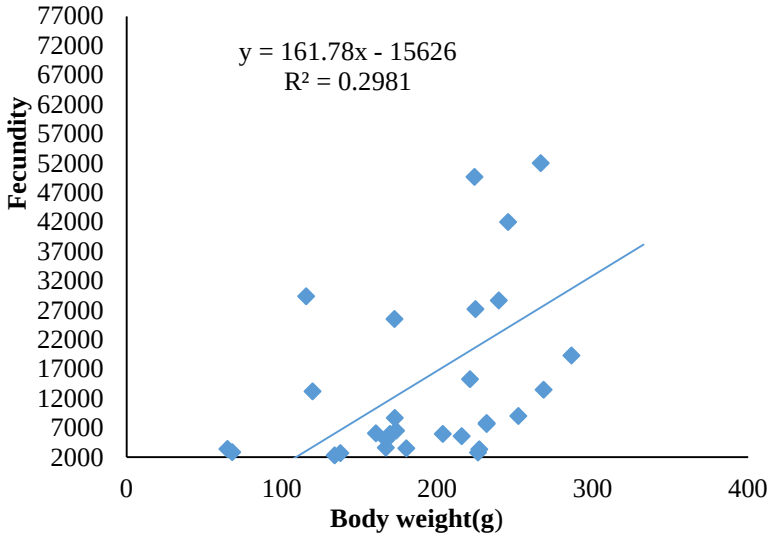


Figure 6 Body weight and fecundity relationship of *Rastrelliger kanagurta*

The relationship between the fecundity (F) and ovary weight (OW)

The relationship between fecundity (F) and ovary weight (OW) was calculated and it was F = 2582.2 OW + 4713.7 (R^2 = 0.6647). The relationship between fecundity and ovary weight was found in linear and fecundity generally increased with the increase in ovary weight. (Fig. 7)

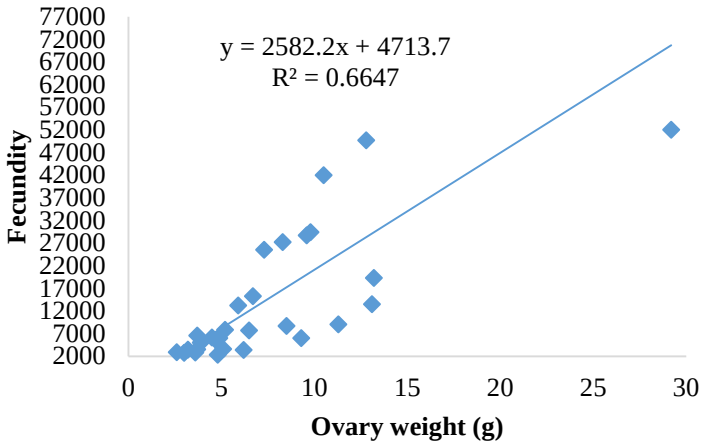


Figure 7 Ovary weight and fecundity relationship of *Rastrelliger kanagurta*

Body length and body weight increased with its fecundity. The number of ova generally increased with increase in length and weight. The calculated R^2values showed better correlation between the fecundity and ovary weight. In this study period, the correlation between fecundity and ovary weight showed more correlation than that of total length and fish weight. The results indicated that the number of eggs per female increased with the increase of length, body weight and ovary weight.

Reproductive condition of *Rastrelliger kanagurta*

Two reproductive cycles in males and females were observed with similar reproductive development. The values of GSI and HSI in males and females were described in Table (5).

Table 5 Monthly GSI and HSI values of males and females of *Rastrelliger kanagurta*

Months	Male		Female	
	GSI (%)	HSI (%)	GSI (%)	HSI (%)
January	1.2	0.9	1.5	1.4
February	2.1	0.8	2.3	0.9
March	1.7	1.5	1.5	1.7
April	2.0	0.9	1.9	1.1
May	2.9	1.3	3.8	1.2
June	1.2	1.4	1.4	1.5
July	1.7	1.1	2.5	0.9
August	2.8	1.2	3.9	1.1
September	1.9	1.1	2.6	0.9
October	2.7	0.5	3.4	0.7
November	1.2	0.7	1.9	0.8
December	2.8	0.6	4.2	1.0

The highest GSI value of female was found in May 3.8%, August 3.9%and October3.4% and Dec 4.2%. The lowest GSI value of female was in June 1.4%. The highest GSI value of male was found in May 2.9%, August 2.8% and October 2.7% and the lowest in January and June (1.2%). The spawning period was determined by monthly evaluation of the gonadosomatic index and maturity stages of oocytes.

The highest values of HSI in males and females (1.7%) were found in March. The lowest HSI value 0.7% was in October. GSI value was negatively correlated with HSI (Fig.8, 9).

GSI was highest for both males and females during the month of May, August, October and December showing occurrence of more ripe individuals.

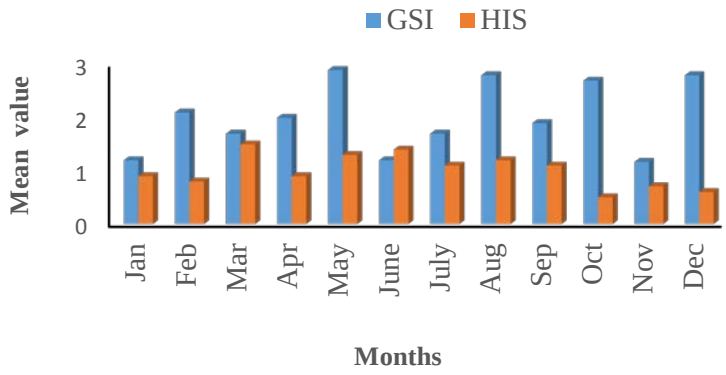


Figure 8 Monthly mean GSI and HSI of male *Rastrelliger kanagurta*

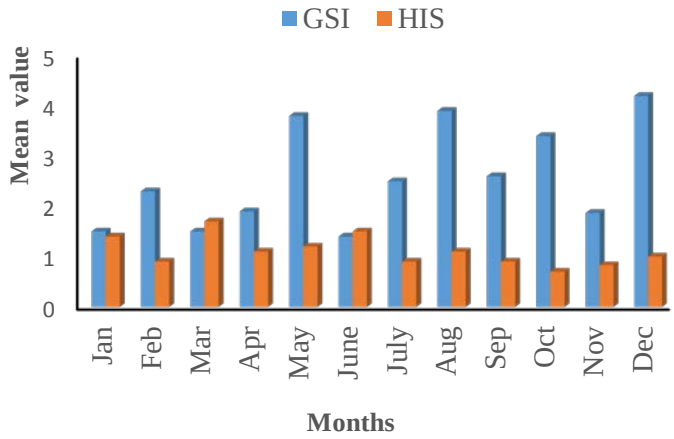


Figure 9 Monthly mean GSI and HSI of female *Rastrelliger kanagurta*

Maturity stages of *Rastrelliger kanagurta*

The maturity stages of males were classified into six stages. Stage I was dominant in January (30%). Stage V was dominant in February (40%), May (55%) and August (50%) and December (45%). Stage VI was not found in May, August, October and December (Fig.10).

The gonadal maturity of females during the studied period was classified as stages I, II, III, IV, V and VI. The stage V was the most dominant in May 53.46%, August 54.25%, October 50.81% and December 50.2%. Stage I (immature stage) was observed dominant in January 29 %. Stage VI (spent stage) was observed in February 20% and June 31%. The stage I, II, III and IV were observed throughout the year. All the six stages occurred in the month of January, February, September and November (Fig. 11).

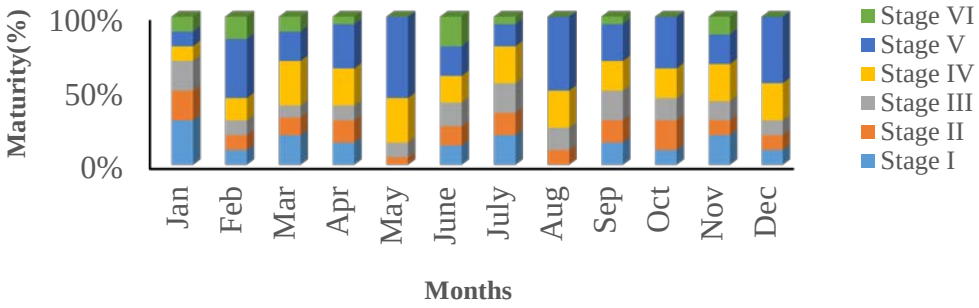


Figure 10 Monthly maturity stages of male *Rastrelliger kanagurta*

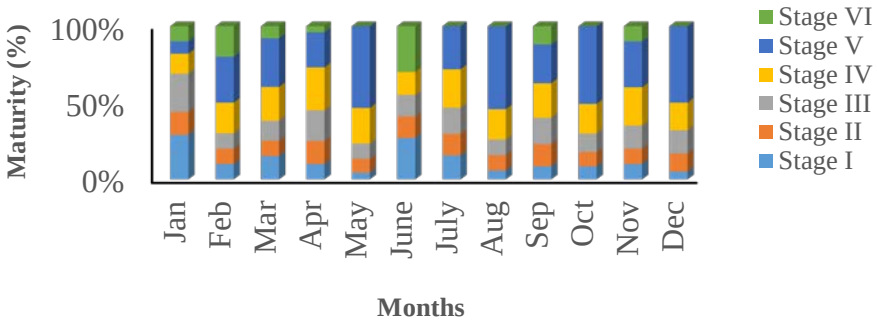


Figure 11 Monthly maturity stages of female *Rastrelliger kanagurta*

Gross morphology of gonad development of male *Rastrelliger kanagurta*

Testes morphology of male *Rastrelliger kanagurta* was classified into six stages based on its external appearance.

Immature- -Testes were elongated, pinkish-white, and transparent membrane. The testis occupied one-third of the body cavity.

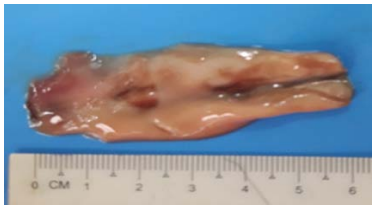
Maturing 1-Testes were in less lobular shape, pinkish white, semi-transparent and easily visible to the naked eye and occupied one-half of the body length.

Maturing 2-Testes were creamy-white, occupying about third-fourth of the body cavity.

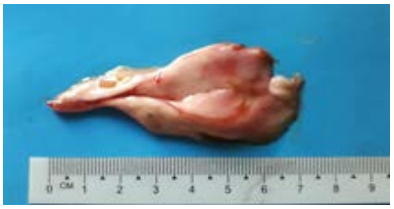
Mature -Testes were large, white to creamy, drops of milt produced when pressed, two stages.

Spawning -Testes were creamy white, soft, lobulation and transparent. Weight and volume increased than mature stage, two third of the body cavity and the pressure to the abdomen, milt flowed out. The left was very slightly larger than the right.

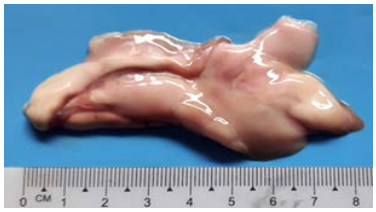
Spent -Testes were shrunken, flaccid, dirty white in color and one-third of the body cavity.



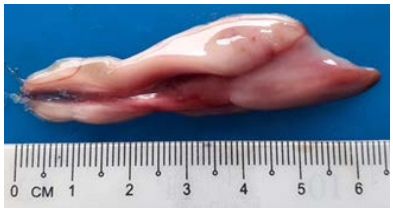
(A) Immature



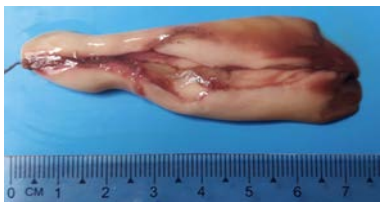
(B) Maturing 1



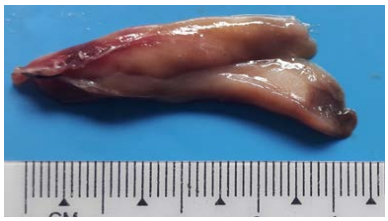
(C) Maturing 2



(D) Mature



(E) Spawning



(F) Spent

Plate 1 Macroscopic developmental stages of male *Rastrelliger kanagurta*

Histological observation of gonad development of male *Rastrelliger kanagurta*

Primary spermatogonia (Stage 1) -This was primary stage of spermatogenesis, which had the largest germ cell, irregularly shaped in the germinal epithelium tissue. These cells were divided and formed primary and secondary spermatocytes.

Secondary spermatogonia (Stage II) - They were structurally similar to spermatogonia except in their sizes. These cells divided and formed primary and secondary spermatocytes.

Primary spermatocytes (Stage III)-They were spherical or oval shape and presented either singly or in small groups. Spermatocytes were more in number with the spermatogonia. Distinctive changes from spermatogonia to spermatocytes was found and decreased in size. They produced secondary spermatocytes.

Secondary spermatocytes (Stage IV) -They were morphologically similar to primary spermatocytes though somewhat smaller and darker. The major difference was the slight reduction in size of the secondary spermatocytes.

Spermatids (Stage V)-Secondary spermatocytes produced spermatids. Spermatids were strongly basophilic spherical cells. They became uniformly condensed in this stage.

Spermatozoa (Stage VI) - Few spermatozoa in sperm duct and more spermatocytes were found. Accumulation of mature spermatozoa was found in the lumen of seminiferous lobules. This stage was the final maturation of the spermatogenesis.

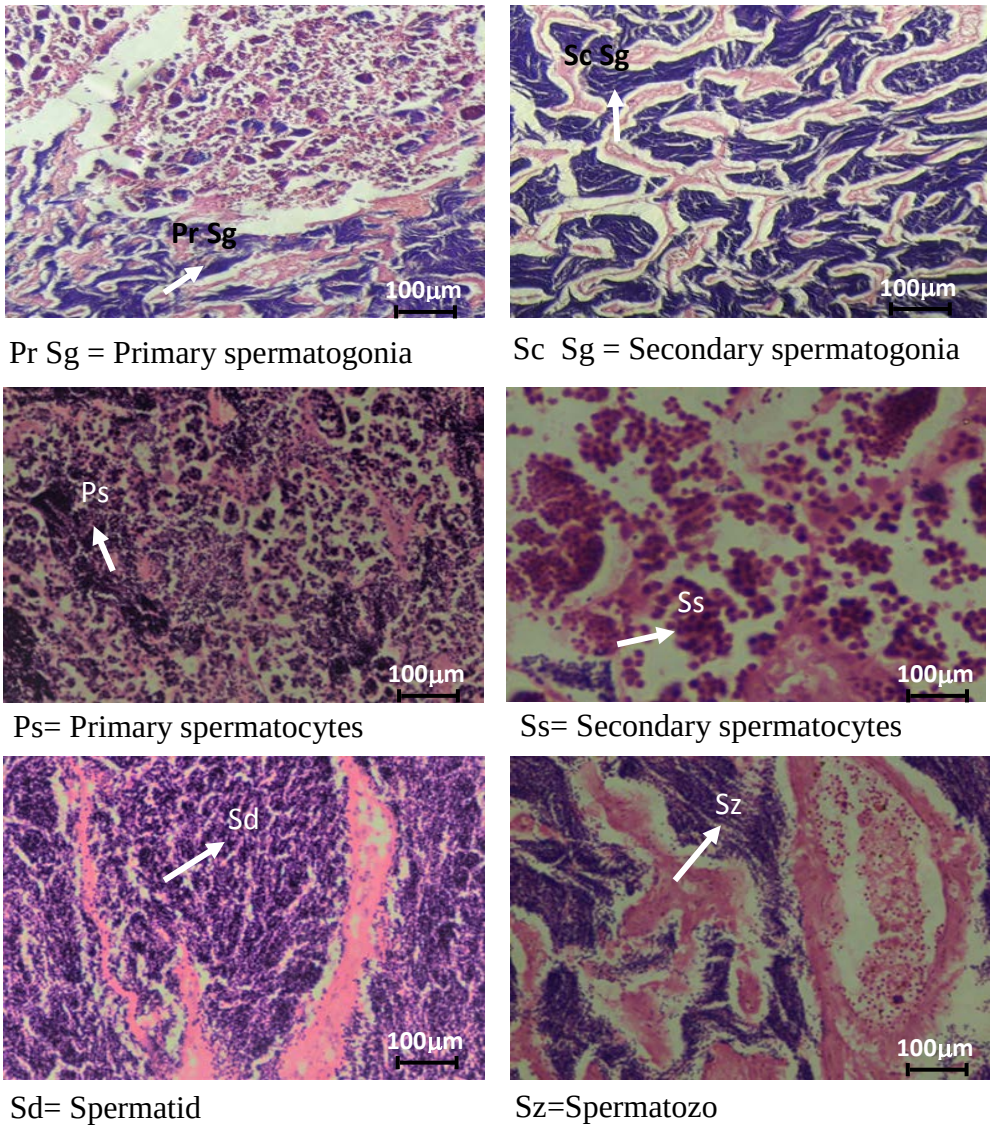


Plate 2 Microscopic developmental stages of male *Rastrelliger kanagurta*

Gross morphology of gonad development of female *Rastrelliger kanagurta*

Ovaries morphology of female *Rastrelliger kanagurta* was classified into six stages based on its external appearance.

Immature- Ovary was relatively small, translucent; Pinkish in color not visible to the naked eye; Occupied about one fourth of the body cavity.

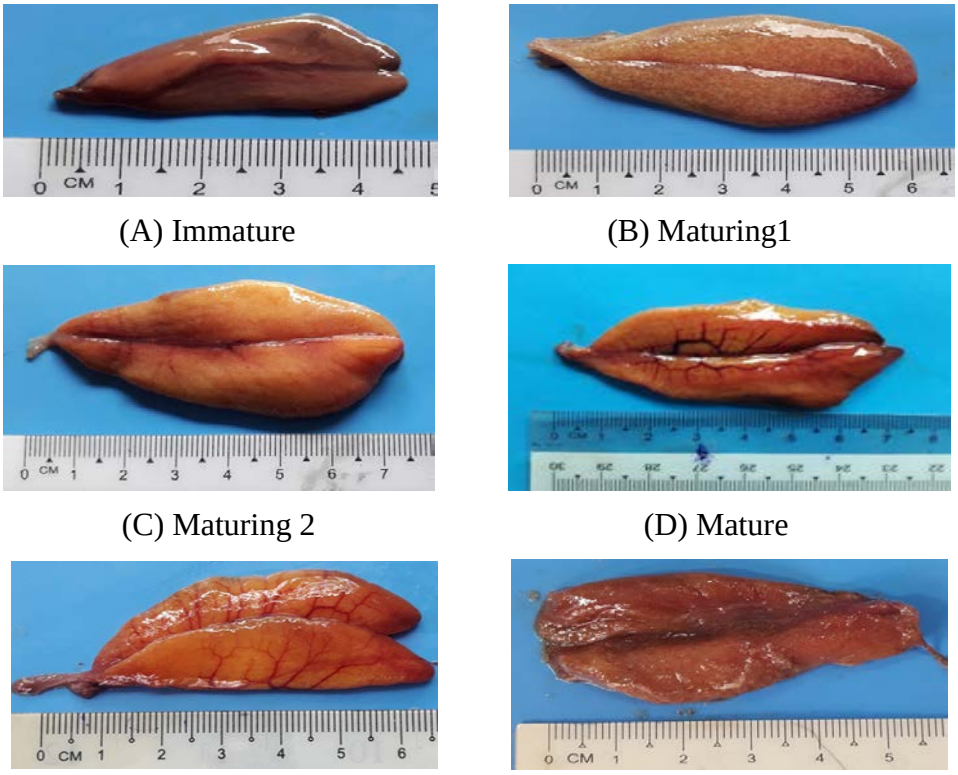
Maturing 1 - The ovary became pale yellow in color and increased in size. Ova were not clearly visible to the naked eye. Blood capillaries were conspicuous and occupied one third of the body cavity of the fish.

Maturing 2 -The ovary became pale yellowish in color and increased in size; Blood vessels visible in dorsal side and occupied one half of the body cavity of the fish.

Mature - Yellowish enlarged ovary occupied nearly two third of the body cavity round section and transparent prominent vascularization. Ovaries appeared granular due to the eggs that were visible to the naked eye. Eggs were not extruded with pressure on the abdomen.

Spawning -The ovary was golden yellow in color filled up with ripe eggs. Blood vessels were still prominent. Transparent ripe ova were clearly visible through the thin ovary wall.

Spent: Ovary was shrunken and flaccid, contained a few whitish residual eggs. Blood vessels were not prominent. Ovaries were smaller and lighter in color than in previous stages, but still reddish brown in color.



(A) Immature (B) Maturing1

(C) Maturing 2 (D) Mature

(E) Spawning (F) Spent

Plate 3 Macroscopic developmental stages of female *Rastrelliger kanagurta*

Histological observation of gonad development of female *Rastrelliger kanagurta*

Chromatin nucleolus (Stage I)- The cytoplasm of these cells were thin and the nucleus was large and rounded, the chromatin nucleolus oocytes, which were observed only in immature females. Oocytes were more abundant than perinucleolar stage oocytes. The oocytes nucleus contained the nucleolus.

Perinucleolus (Stage II) - The cytoplasm was more basophilic than in the previous stage, with a gradual decrease according to the increase in cell size. This stage was characterized by more regular in shape and increased in size of the oocytes, caused by enlargement of the nucleus as well as the cytoplasm. The increase in number of nucleoli indicated increasing nuclear activity.

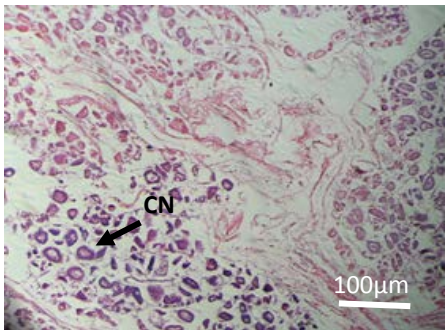
Cortical alveoli (Stage III) – It appeared in the periphery of the cytoplasm. The nucleus and cytoplasm increased compared to the previous stage. Nucleoli and the number of yolk vesicle also increased. A few oil droplets were observed in the cytoplasm around the nucleus. The wall of the ovary was thicker and some oocytes beginning to undergo vitellogenesis with yolk granules on the cytoplasm.

Vitellogenesis (Stage IV) - The deposition of yolk granules was seen at the periphery of the cytoplasm. The vitelline membrane became thicker and follicular cells grew. In this stage, yolk granules rapidly increased in size and number. Yolk granules were densely packed and occupied

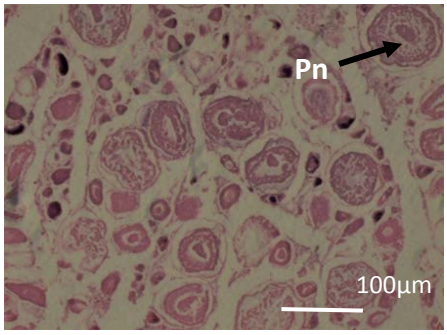
the total volume of the cytoplasm. Large number of nucleoli was observed around the peripheral of nucleus.

Maturation(Stage V) -The nucleus retained with very small nucleoli, lost its spherical shape and shrunk. The vitelline membrane was radially arranged around the oocyte. In this stage, yolk granules and oil droplets continued to increase in size and number, primary and secondary yolk stage also numerous, vacuoles gradually increased in the periphery and central zones. The size of the nucleus was small .The tertiary yolk stage oocytes underwent maturation.

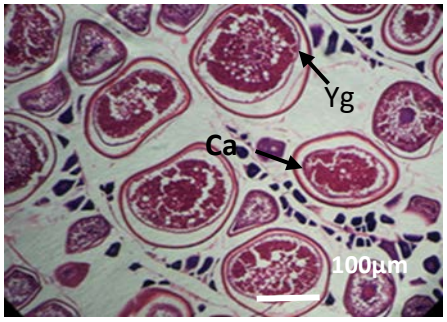
Ovulation(Stage VI)- The ovary showed atretic and discharged follicles, along with stage I and II of oocytes. Post-ovulatory follicles were clearly seen.



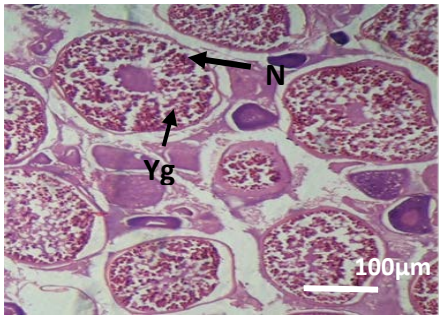
STAGE I. Chromatin nucleolus



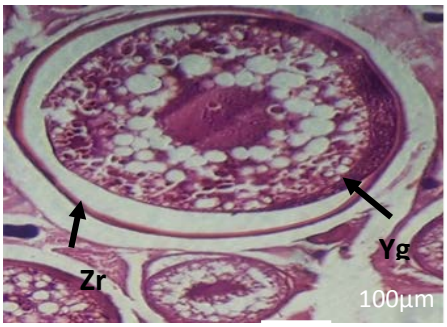
STAGE II. Perinucleolus



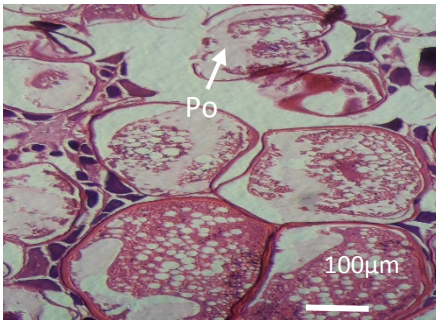
STAGE III. Cortical alveoli
Yg=yolk granule , Ca=cortical alveoli



STAGE IV.Vitellogenesis
Yg=yolk granule, N=nucleus



STAGE V. Maturation
Yg=yolk granule,Z =zona radiata



STAGE VI. Ovulation
Po=postovulatory follicle

Plate 4 Microscopic developmental stages of female *Rastrelliger kanagurta*

Discussion

In the present study, the fish length and weight relationships of male ($W = 0.0277\ L^{3.2159}$, $R^2 = 0.7455$) and female ($W = 0.0293\ L^{3.7046}$, $R^2 = 0.7652$) were investigated. The value of b>3 was found in this study. Length-weight relationship of Indian mackerel was $W = 0.005L^{3\cdot21}$ and having linear growth (Abdurrahman *et al*., 2004 and Gupta, 2004). Hulkoti (2005) reported that length-weight relationship did not show significant difference in both sexes of *R. kanagurta* in the Western Coast of India. Pradhan (1956) stated that length-weight relationship of Indian mackerels was allometric growth. The result supported to the prior researches.

During the studied period, the sex-ratio of *R. kanagurta* showed that the most of the months had equal proportion of males and females. The overall male and female ratio was 1:1.2. Hulkoti (2005) observed the sex ratio of *R. kanagurta* of male: female as 1:0.9 which is in agreement with the present finding. Observation of the fish sex ratio is important for population structure studies. The sex ratio of male and female (1: 1) indicates that the population is in a balanced state in nature.

The spawning period was May (3.8%), August (3.9%), October (3.4%) and December (4.2%) at that time as indicated by GSI peak values. Hulkoti (2005) assessed the values of GSI peaks in July and August indicating the spawning period of this fish. In the present investigation, the gonado somatic index (GSI) increased more obviously in females than males. The monthly GSI values of males and females were in a similar mode, higher values of GSI coincided with spawning period. Male always showed lower gonad somatic index (GSI) values than female due to higher ovary weight compared to testes. Basically, the spawning season determined the occurrence of maturing, mature, and spent stages of individuals. Higher values of GSI are regarded as indicative of spawning season. The present study showed that *R. kanagurta* spawned during all the year, especially with high values in May, August, October and December.

Maturity estimations were based on monthly changes in gonado somatic index in both sexes. Yohannan and Abdurahiman (1998) observed that the indian mackerel spawned in succession and recruitment during the monsoon period in India. In this study the peak reproductive action is coinciding with the monsoon season since it has abundant food supply and the favorable period for larval surviving. Rainboth (1991) pointed out that the rainy season and spawning peaks of fishes were highly correlated.

In the present study, the relation between the spawning period of *Rastrelliger kanagurta* and annual cycle of rainfall was found. The highest GSI was found in July and August which is typically associated with the raining season in Myanmar.

The estimation of fecundity was generally determined by the number of vitellogenic oocytes. During the present study, the relationships between fecundity and total length, body weight, ovary weight of fish were found to be linear. It showed that the fecundity increased with increasing body length, body weight and gonad weight. These observations are in agreement with the observations of Yohannan and Sivadas (2003). During the present study, the absolute fecundity of ripe females was found with 2300 eggs to 78000 eggs. Rao (1967) stated that absolute fecundity of mackerel ranged from 20,911 to111, 000 eggs and Antony Raja and Bande (1972) presented the average fecundity of 38,000 eggs.

Five different stages of maturity were found in most of the months however spent stage was observed in June. Abdussamad, *et al*., (2010) indicated that the spawning stage of Indian mackerel was highly abundant during March to May. Moreover, Hulkoti (2005) observed that spawning season of mackerel extended from June to September.

Longhurst and Pauly (1987) stated that the maturation is a continuous process resulting in the occurrence of mature fishes throughout the year. Abdussamad, *et al.,* (2006) reported the

progress of gonad that depended on the environmental condition occurring throughout the year. In the same fish species of the different areas, the peak of ovarian maturation may be variable due to divergence ecological conditions.

It can be concluded that the females of *R.kanagurta* have three peaks of spawning time in May, August and October. It is recommended to define batch spawners. Size of both sex organs increased as it attained the stage of maturity to produce fully matured gametes. *Rastrelliger kanagurta* was capable of spawning for multiple times.

Lowe-Mc Connell (1987) observed that fish species in tropical river systems were generally noted for very rapid maturation and multiple spawning behavior which was an adaptive response to fluctuations in water level. Wootton (1990) also stated that the liver weight (HSI) decreased as the ovary weight increased during vitellogenesis. The release of energy from the liver into the ovary supports the condition that GSI and HSI values were inversely related with each other as recorded in the present study. Hepatosomatic index and gonadosomatic index were inversely proportional to each other and showed a high hepatic activity. This showed that HSI has reverse action on GSI.

Seifaddini *et.al* (2014) stated the reproductive cycle of the female Indian mackerel, *Rastrelliger kanagurta*, where it demonstrated six stages of ovary maturity and six oocyte developmental stages in the northern Persian Gulf and Oman Sea. In the present study, six different stages of maturity were found in most of the months however spent stage was observed in January and June. Histological examinations indicated the similar gonadal development having six stages of spermatogenesis and oogenesis in the present study.

Conclusion

Understanding the reproductive biology of the species is an important requirement for scientific advice on artificial breeding of Indian Mackerel. The present investigation will contribute to the long-term productivity of *Rastrelliger kanagurta*. Our findings revealed that the studied fish had four distinct spawning peaks in May, August, October and December. Gonad development suggested a pattern of continuous breeding. These results have important implications for the breeding of *Rastrelliger kanagurta* as they demonstrate the potential for induced breeding without being constrained by seasonal variation in reproductive activity. Further research in this area could lead to significant advances in production and management of *Rastrelliger kanagurta*.

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