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Research Article

Reproductive Biology of the Indian Mackerel, *Rastrelliger kanagurta* (Cuvier 1817), from Salalah, Dhofar Coast, Oman

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Abstract: The present study aims at determining the length-weight relationship, sex ratio, relative weight, gonadosomatic indices and length at 50% maturation for the Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1817). A total of 791 specimens were collected from Salalah in the Dhofar region during the years 2007 to 2009. For both sexes, a common length-weight relationship was derived from the analysis, that is $W = 0.00001 \times L^{3.4}$. It was found that the Omani Indian mackerel spawned during August to November and the lengths at 50% maturation were 271 mm for the combined sexes, 267.5 mm for the females and 277.5 mm for the males. The relative condition weight was positively proportion to the gonadosomatic index. The mean sex ratio for the entire fish sample of 0.56±0.1 was significantly different from the anticipated theoretical sex ratio of 0.5 ($X^2 = 8.77$; df = 1; $p<0.05$).

Keywords: Dhofar, Indian mackerel, Oman, *Rastrelliger kanagurta*, reproduction

INTRODUCTION

Among the small pelagic fisheries that are found along the Salalah coast, the Indian mackerel (*Rastrelliger kanagurta* (Cuvier, 1817)) is regarded as one of the significant fisheries. In 2018, the Indian mackerel landings increased by 77% as compared to the landings in 2017 (Fig. 1). In Salalah, as a result of the increase in landings, the revenue of this fishery showed an increase from 136,000 OR in 2017 to 366,000 OR (1 OR = 2.6 USD) in 2018 (MAF, 2018). At present, the major fishing methods for this species are dominated by the traditional fishermen and they are limited to gillnets and seines (Al-Abdessalaam, 1995; Jayabalan *et al*., 2014; Randall, 1995). There are only few research publications on the Omani Indian Mackerel that are mostly published from the data collected from Muscat, Batinah and Sharqiyah regions (Jayabalan *et al*., 2014, 2016; Zaki *et al*., 2016a). However, there are so far no scientific publications on this subject from the Dhofar region.

The objective of the current study is to present some biological and reproductive information related to *R. kanagurta* from Salalah in the Dhofar region, south of Oman (Fig. 2). The information presented in the current study are the product of data analysis of length-weight relationships, sex ratio, spawning season, length at 50% maturity and relative condition factor. The results of this study will be helpful in understanding the biology and stock assessment *R. kanagurta*, which will be useful for the future management and development of the species.

MATERIALS AND METHODS

The data used in the current analysis were collected as a collaborative project between the Ministry of Agriculture and Fisheries and the National Institute of Water and Atmospheric Research NIWA. This project was carried out during the period 2007 and 2009 in order to assess the small pelagic fishes along the Omani coast (Zaki *et al*., 2016a). In all, 791 Indian mackerels were used for the analysis. For the NIWA project, on a monthly basis, the samples were randomly collected from the Salalah central fish market and also from the landing sites from November 2007 to 2008. The total length (to the nearest of 1 mm), total weight (to the nearest of 1 g), sex and gonad weight (to the nearest of 0.001 g) of the samples were recorded. In addition, the maturity stages for *R. kanagurta* were identified

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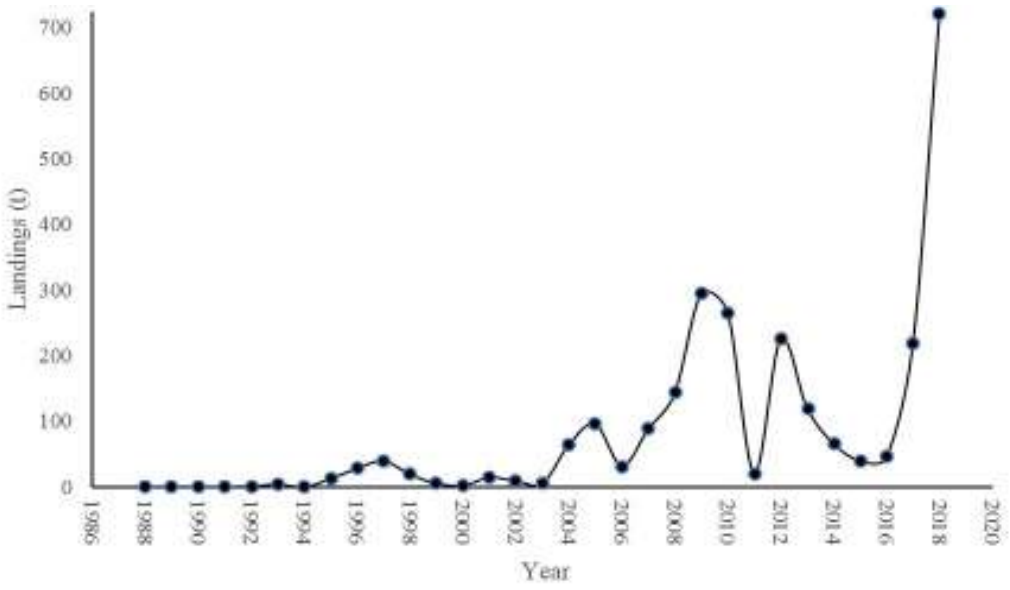


Fig. 1: Indian mackerel landings (t) at the Dhofar landings

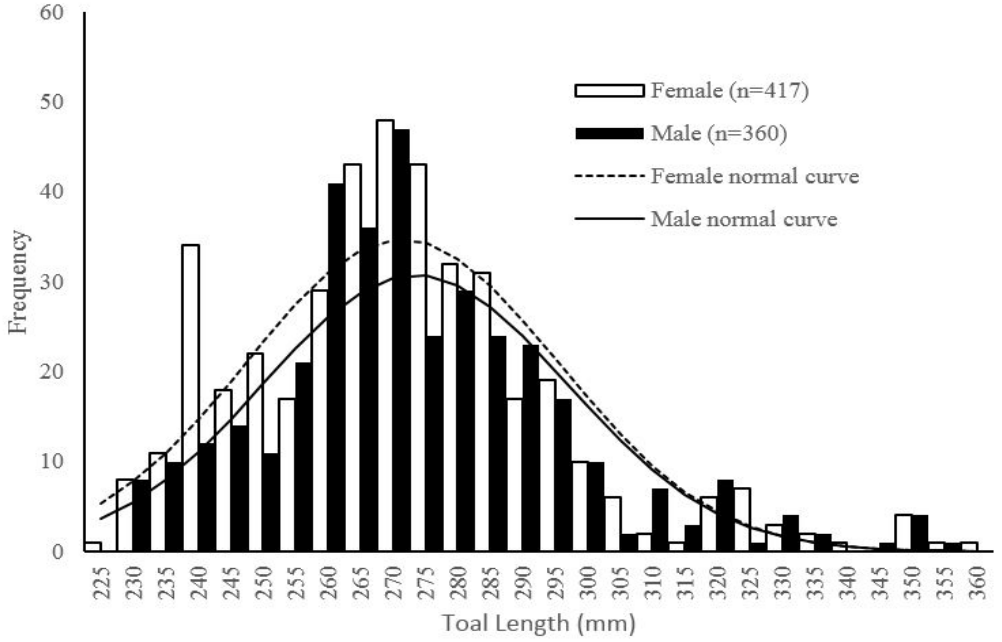


Fig. 2: The length-frequency distribution of the Indian mackerel samples analyzed in the study, with normal curves superimposed on female samples
Dashed line: Female samples; Straight line: Male samples

according to Pradhan and Palekar (1956) with modification by the work of Zaki *et al*. (2016b).

A total of 359 males, 416 females and 774 combined sexes were used for the length-weight relationships analysis. The length-weight relationships were obtained by the exponential equation (Ricker, 1975):

$$W = a \times TL^b$$

where,

W : The fish weight (g)
TL : Total length (mm)
"a" and "b" : The regression coefficients

Relative weight, which is used to measure the fish condition was estimated by following formula:

$$W_r = \left(\frac{W}{a \times TL^b}\right)$$

where,

W_r : The relative weight of the fish
W : The actual weight of the fish
TL : The fish length
"a" and "b" : The regression coefficients obtained from all fish sample data collectively

Sex ratios were estimated as total number of females by the sum of males and females. Furthermore, the sex ratios were tested to find out if they were different from the expected sex ratio of 0.5 using the chi-square (χ^2). The sex ratios were analyzed every month for different length groups. Monthly Gonadosomatic Indices (GSI), that is calculated for indicating the fish spawning season, were calculated by:

$$\text{GSI} = \frac{\text{Gonad weight}}{\text{Fish weight}} \times 100 \text{ (Strum, 1978)}$$

Cumulative frequency (f, %) was used to obtain maturation length at 50% ($L_{50\%}$) for the combined sexes, male and female fish samples.

RESULTS AND DISCUSSION

During November 2007 to 2008, a total of 776 Indian mackerel were analyzed to present the length and weight frequencies. In the present study, the total sample comprised of more female *R. kanagurta* (417 (54%)) than male (360 (46%)). During November 2007 and December 2007 sampling, both the smallest and largest fish were found to be females. Males ranged from 230 to 353 mm with a mean length of 272±23.3 mm, while the females ranged from 225 to 360 mm with a mean of 270±24.0 mm. The total length for the combined sexes ranged from 225 to 360 mm with a mean length of 271±23.6 mm and modal length of 270 mm. On the other hand, the total weight for the specimens ranged from 133 to 612 g with a mean of 262.18±83.89 g and modal weight of 259 g. Total weight for females ranged from 136 to 583 g, while for the males it ranged from 133 to 612 g. The results indicated that the males were heavier (mean 268.1±84.37 g) than the females (mean 257.05±83.24 g). The results indicated no significant difference in the length ($t = 1.14$; $df = 763$; $p = 0.25$) and weight ($t = 1.83$; $df = 755$; $p = 0.07$) for the males and females, respectively.

In all, 694 Indian mackerels were used for sex ratios analysis, the female (n = 386)-to-male (n = 308) sex ratio was 0.56 for the entire fish sample. The mean sex ratio for the entire fish sample of 0.56±0.1 was significantly different from the anticipated theoretical sex ratio of 0.5 ($\chi^2 = 8.77$; $df = 1$; $p<0.05$). The monthly sex ratio favored the females over males and ranged from 0.35 in April 2008 to 0.65 in March 2008. However, males were found to dominate the April and November 2008 samples (Fig. 3). As a result, females dominated in all length classes except the 290-, 310-320- and 330-cm-length classes (Table 1).

Length-weight relationship and length at 50% maturity: For analyzing the length at 50% maturation, 416 females and 360 males ranging in total length from 225 to 360 and 230 to 353 mm were analyzed. The results of the cumulative frequency analysis (%f) showed that the length at 50% maturity was 271 mm for the combined sexes, 267.5 mm for the females and 277.5 mm for the males (Fig. 4a to 4c). The smallest mature fish was a female that measured 225 mm and weighed 136 g.

In all, 415 females and 359 males were analyzed for the length-weight analysis. The results depicted a

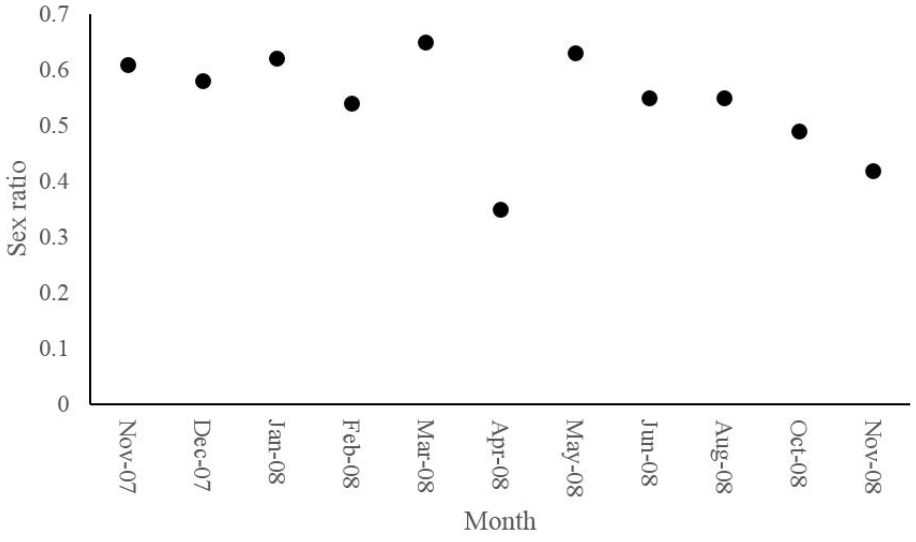
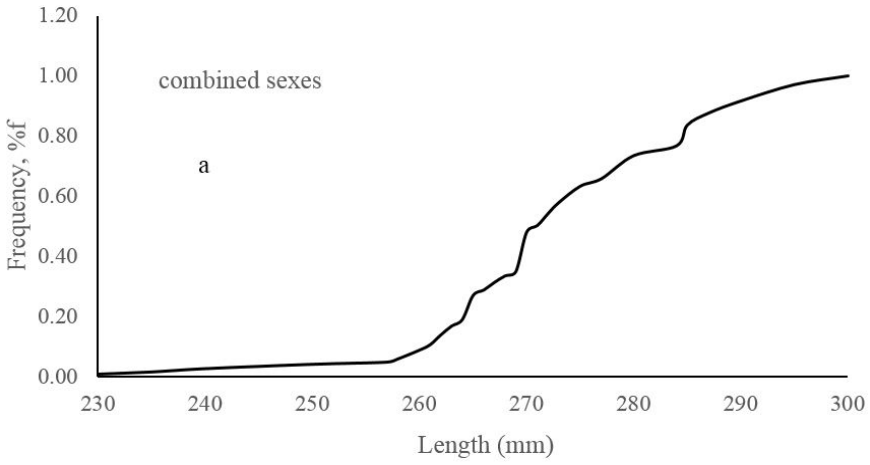
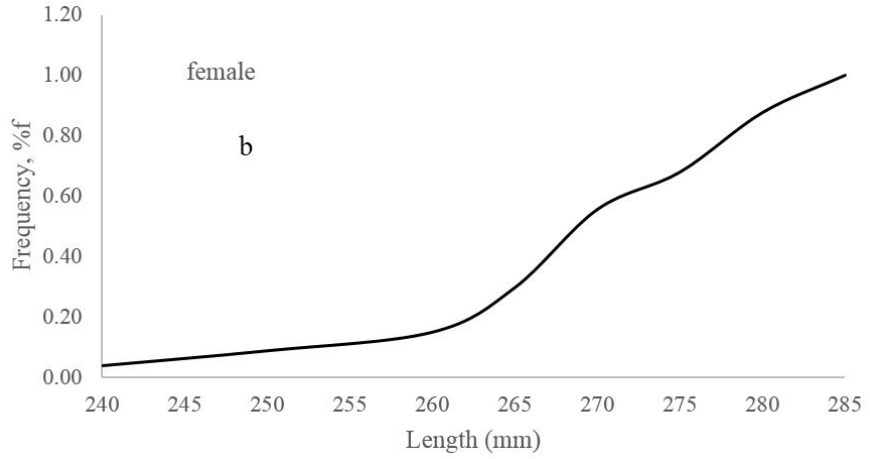


Fig. 3: Monthly sex ratio distribution of the Indian mackerel

Table 1: Sex ration distribution by length

TL (cm)	Males (n = 360)	Females (n = 417)	Sex ratio	Chi-square (χ^2)	p-value
225	0	1	1.00	1.00	0.320
230	8	8	0.50	0.00	1.000
235	10	11	0.52	0.08	0.830
240	12	34	0.74	10.52	0.001
245	14	18	0.56	0.50	0.480
250	11	22	0.67	3.67	0.060
255	21	17	0.45	0.42	0.520
260	41	29	0.41	2.06	0.150
265	36	43	0.54	0.62	0.430
270	47	48	0.51	0.01	0.920
275	24	43	0.64	5.39	0.020
280	29	32	0.52	0.15	0.700
285	24	31	0.56	0.89	0.350
290	23	17	0.43	0.90	0.340
295	17	19	0.53	0.11	0.740
300	10	10	0.50	0.00	1.000
305	2	6	0.75	2.00	0.160
310	7	2	0.22	2.78	0.100
315	3	1	0.25	1.00	0.320
320	8	6	0.43	0.90	0.600
325	1	7	0.88	4.50	0.030
330	4	3	0.43	0.14	0.710
335	2	2	0.50	0.00	1.000
340	0	1	1.00	1.00	0.320
345	1	0	0.00	1.00	0.320
350	4	4	0.50	0.00	1.000
355	1	1	0.50	0.00	1.000
360	0	1	1.00	1.00	0.320





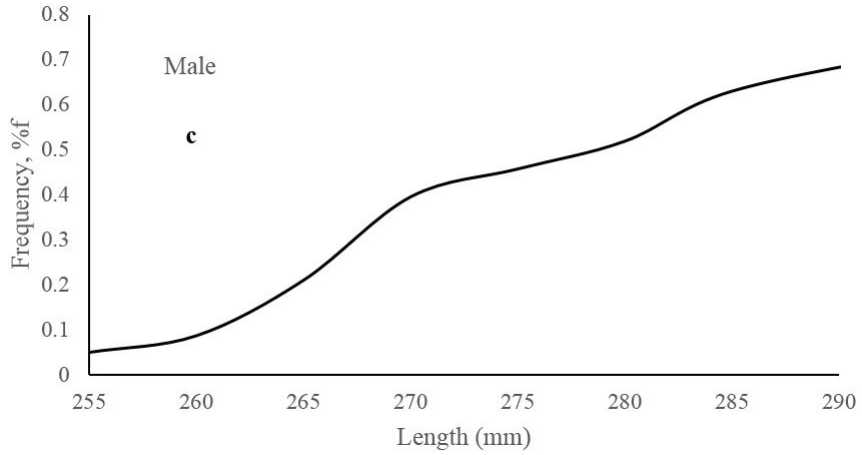


Fig. 4: Cumulative frequency (%f) for (a) Combined sexes, (b) Female and (c) Male Indian mackerel

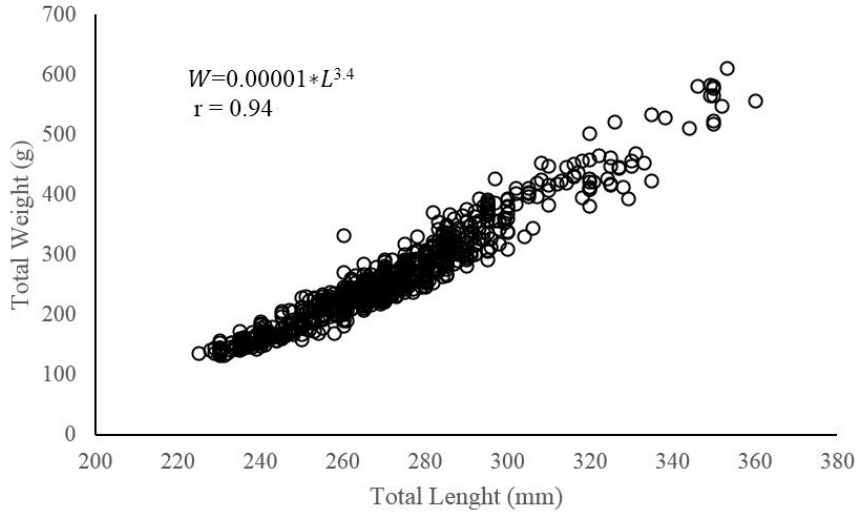


Fig. 5: Length-weight relationship of the entire sample

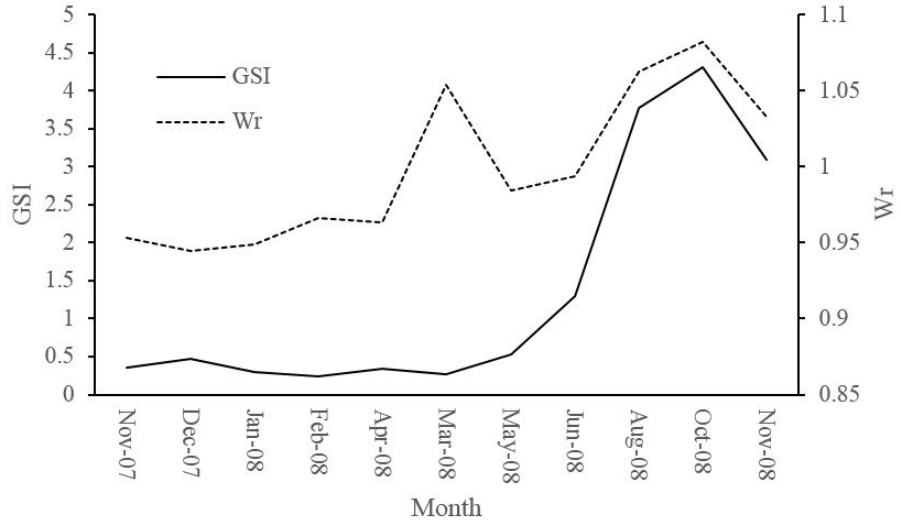


Fig. 6: Graph showing variation in the monthly gonadosomatic index and relative weight of Indian mackerel

common relationship for the whole sample, males and females combined were "$W = 0.00001 \times L^{3.4}$, with r = 0.94 (Fig. 5). The overall b-value (b = 3.4) obtained was proved to be different from the expected b-value of 3 (t = 13.27; df = 772; p>0.05).

Annual variation in the gonadosomatic index and the relative weight (W_r): During the sampling period, the GSI values for the combined sexes were observed to be at low levels till June 2008. The values started to increase and reached a peak from August to November 2008 (Fig. 6). The mean GSI during the sampling period was 1.36±1.57 for the combined sexes, while the sample mean during the spawning period was 3.73±2.30. On the other hand, the mean GSI during non-spawning period was 0.48±0.52. During the sampling period, the relative weight W_r fluctuated monthly and ranged between 0.79 and 1.52 g with a mean of 1±0.05. During the study, the values of relative weight for Indian mackerel were positively proportional to the GSI values (Fig. 6).

In general, the monthly sex ratios favored females except for months April and November 2008. Monthly sex ratio ranged from 0.35 in April 2008 to 0.65 in March 2008. This result was also supported by a similar study conducted in Mahout from the Al-Wusta region of Oman, where the female Indian mackerels dominated the samples and the annual male to female ratio was 1:1.57 during 2007-2008 and 1:1.29 during 2008-2009 (Zaki *et al*., 2016a). On the other hand, sex ratio was found to be close to 1:1 for the samples collected from Western Waters of Aceh (Iran) (Arrafi *et al*., 2016) and from Pakistan coast (Moazzam *et al*., 2005). The results of the present study also corresponded to the results of Zaki *et al*. (2016b), as they also found that the data for the sex ratios of the samples collected during 2007-2008 proved to be significantly different from the expected theoretical sex ratio of 0.5. In contrast, the males were found to dominate in the samples that were collected from Kompleks Lembaga Kemajuan Ikan Malaysia (LKIM), Kuantan, Pahang, Malaysia, in 2012. The results indicated that out of 329 specimens, 190 (57.75%) were males and 139 (42.25%) were females (Rahman and Hafzath, 2012).

Length-weight relationship and length at 50% maturation: The length-weight data analysis resulted in the same relationships as for the combined sexes, females and males "$W = 0.00001 \times L^{3.4}$" (n = 774 where females were 415 and males 359 and r = 0.94). A common length-weight equation was also reported in samples collected from Muscat (Oman), $W = 0.0101L^{3.1}$ ($R^2 = 0.92$) (Jayabalan *et al*., 2016). Similarly, common length-weight relationships were reported in Sohar samples (Oman) as well, $W = 0.0035TL^{3.3881}$ (Jayabalan *et al*., 2014). In addition, a common length-weight relationship was also reported by Sivadas *et al*. (2006) to be W = 0.0000014 L (n = 800, r = 0.98). Several other studies have also reported similar results for *R. kanagurta* (Gopakumar *et al*., 1991; Abdussamad *et al*., 2006; Jayabalan *et al*., 2014). The "b" values for length-weight relationships of *R. kanagurta* were reported to range from as low as 2.63 to 3.48 (Abdurahiman *et al*., 2004; Rohit and Gupta, 2004; Moazzam *et al*., 2005; Abdussamad *et al*., 2006; Jayabalan *et al*., 2014; Arrafi *et al*., 2016). The "b" value estimated in the current study was 3.4.

The results of the cumulative frequency analysis (%f) indicated that the length at 50% maturity was 271 cm for the combined sexes, 267.5 cm for the females and 277.5 cm for the males. Zaki *et al*. (2016a) reported 252 and 257 mm for the males and females, respectively. While Bintoro *et al*. (2019) reported that the length for female and male fish was 22.47 and 22.85 cm, respectively.

Spawning: In the present study one spawning period was observed that extended through August-November, this is also supported by the works of Arrafi *et al*. (2016) and Rohit and Gupta (2004). Literature review indicated a different spawning season for *R. kanagurta* indicating one season through the year with multiple spawning peaks (Rao, 1967; Potier and Nurhakim, 1995; Mosse and Hutubessy, 1996; Arrafi *et al*., 2016; Zaki *et al*., 2016a). This suggests that *R. kanagurta* is a batch fecund fish and may use any good environmental conditions to spawn (Zaki *et al*., 2011). The condition factor expressed by the relative weight in this study was proportional to the spawning season, which indicates that the fish are in good condition during spawning season. In March, it was observed that the relative weight picked up rapidly, unlike other months of the year, maybe owing to sampling issues, that is, the majority of fish collected in March were well fed. A positive relationship between the condition factor of *R. kanagurta* and spawning season was also observed by other scientists (Rahman and Hafzath, 2012; Arrafi *et al*., 2016). However, unlike the present study, Zaki *et al*. (2016b) could not relate the condition factor (K_n) to spawning activity.

CONCLUSION

This study provided fundamental and basic information on the reproductive biology of the Indian Mackerel, *Rastrelliger kanagurta* (Cuvier 1817), from Salalah, Dhofar Coast, Oman, using data obtained from Dhofar region during the years 2007-2009. The basic information was linked to the length-weight relationship and length at 50% maturity and annual variation in the gonadosomatic index and the relative weight (Wr). The results presented in this study are useful for future fishery management and development.

The Omani Indian mackerel spawn for one extended period between August and November, the length at 50% maturity was 271, 267.5 and 277.5 cm for the combined sexes, females and males, respectively. On the hand, a common length-weight equation was derived from the samples collected during the study period, "$W = 0.00001 \times L^{3.4}$".

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