Maturation, Spawning, and Feeding Habits of the Indian Mackerel *Rastrelliger kanagurta* (Cuvier, 1817) from the Sea of Oman off the Sohar Coast, Sultanate of Oman

Nachiappan Jayabalan, Shama Zaki, Abdulaziz Al-Marzouqi, and Lubna Al-Kharusi

Abstract The reproduction and feeding in the Indian mackerel *Rastrelliger kanagurta* (Cuvier 1817) were studied from the coast of Sohar, Sultanate of Oman from October 2007 to September 2009. The occurrence of spent gonads from April to October shows that the population of fish might spawn for about 7 months. However, the monthly gonadosomatic indices (GSI) and relative condition factor (Kn) fluctuated even during spawning season. Males and females matured (50%) at an average length of 227 and 232 mm respectively. The male to female ratio showed homogeneous distribution of sexes during 2007–2008 and 2008–2009. The fecundity in females ranged from 55,614 eggs to 133,728 eggs and the average fecundity was 93,205 eggs. The fish is a plankton feeder preferring mainly copepods followed by diatoms, crustacean remains, dinoflagellates, fish eggs and molluscan larvae.

Keywords Rastrelliger Kanagurta · Maturation · Spawning · Food and feeding · Sohar coast · Sea of Oman · Oman

1 Introduction

In the northern Indian Ocean region, the Indian mackerel *R. kanagurta* (Cuvier) is commercially harvested by the countries bordering the Red Sea, Sea of Oman, Arabian Gulf, Pakistan, India, Sri Lanka, Bangladesh, Myanmar, Thailand and

N. Jayabalan (✉)
Alga Marine Pvt. Ltd., Chennai, India

Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth, Muscat, Sultanate of Oman

S. Zaki · A. Al-Marzouqi · L. Al-Kharusi
Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth, Muscat, Sultanate of Oman

L. A. Jawad (ed.), *The Arabian Seas: Biodiversity, Environmental Challenges and Conservation Measures*, https://doi.org/10.1007/978-3-030-51506-5_19

Malaysia (Fischer and Whitehead 1974; Collette and Nauen 1983; Fischer and Bianchi 1984; Randall 1995).

From the Omani coasts of the Arabian Sea and Sea of Oman, *R. kanagurta* is harvested by using the artisanal gears such as gill nets, seines and cast nets (Al-Abdessalaam 1995; GoSO 2009). The estimated annual landings of the Indian mackerel from the Sohar coast (Al-Batinah) bordering the Sea of Oman during 2000–2009 ranged from 658 t in 2001 to 1981 t during 2007 (GoSO 2009). Earlier studies on the reproductive biology of *R. kanagurta* from Mahout Coast bordering the Arabian Sea (Zaki et al. 2016) and on the age and growth of the fish from the Sohar coast of the Sea of Oman (Jayabalan et al. 2014) are available. This paper is first of its kind reporting on the aspects of reproduction and food and feeding in *R. kanagurta* from the Sohar coast carried out for 2 years between 2007 and 2009.

2 Materials and Methods

Altogether 1439 specimens landed by gill nets, seines and cast nets were collected at random on monthly basis between October 2007 and September 2009 from Sohar (Fig. 1). However, no sample could be collected during January, June and July during 2007–2008 and during December and March during 2008–2009 due to inclement weather. Immediately after collection, the fish were stored in ice boxes and transported to the laboratory, where the specimens were thoroughly washed in tap water before analyses. For each fish, the total length (TL) to the nearest 1 mm and total wet weight (TW) to the nearest 1 g were recorded using fish measuring board and electronic balance respectively. Then the body cavity of individual fish was cut open to recognize the sex and maturity stage of the gonad, and subsequently the weight of the gonad was recorded to the nearest 0.01 g. Both the gonads and stomachs of fish were preserved in 5% neutral formalin for further analyses.

2.1 Maturation and Spawning

2.1.1 Maturity Stages

Considering the macroscopic appearance and level of filling in body cavity, the ovaries and testes were recognized into seven stages such as I, immature; II, maturing 1; III, maturing 2; IV, maturing 3; V, mature; VI, ripe/running; and VII, spent (Pradhan and Palekar 1956; Zaki et al. 2016).

2.1.2 Length at First Maturity

Estimates of length at first maturity (L_m) for males and females considering maturity stages III and above were obtained by plotting the cumulative maturity percentages against different lengths (10 mm size group) for pooled data of 2 years.

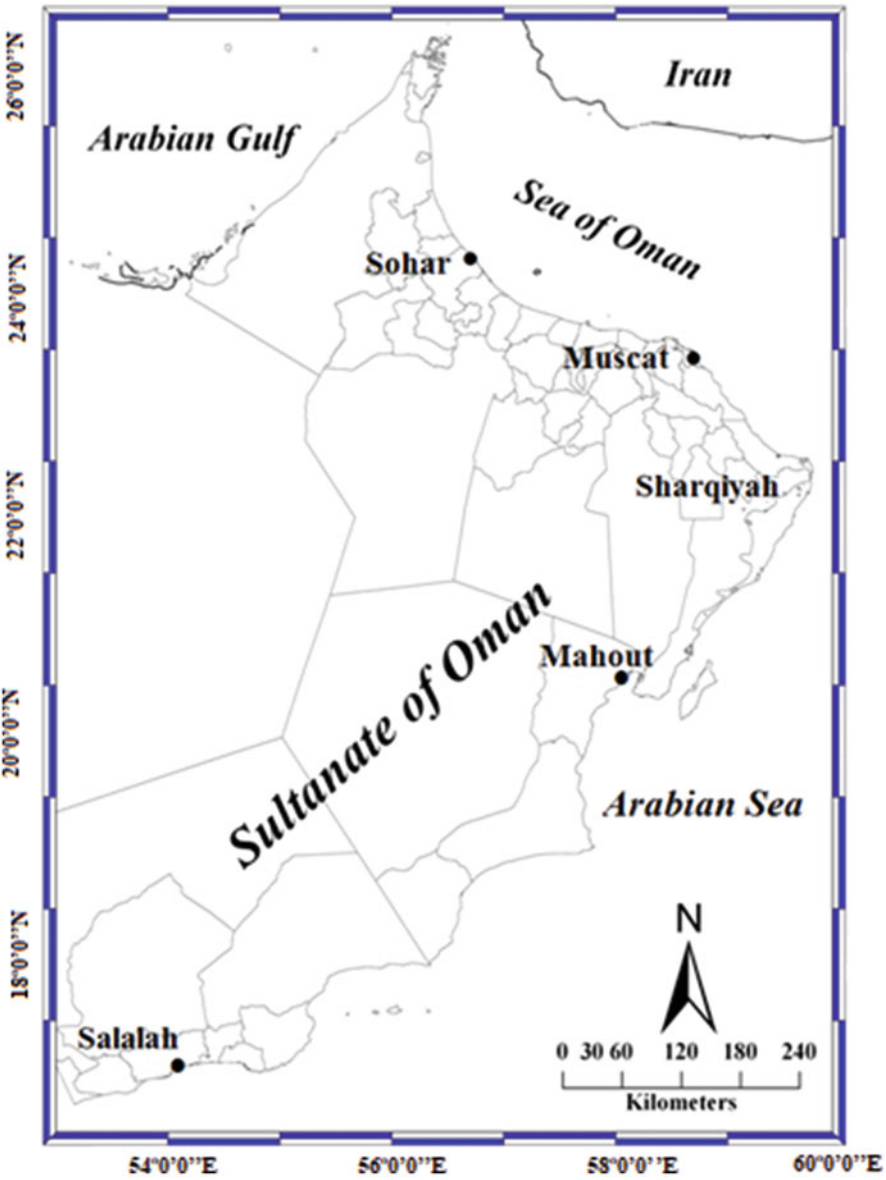

Fig. 1 Map showing different coastal regions and sampling location (Sohar)

2.1.3 Spawning Season

Occurrence of Mature Gonads

The spawning season of *R. kanagurta* was determined by plotting the percentage occurrence of mature gonads during various months.

Gonadosomatic Index
To calculate the monthly gonadosomatic index (GSI), the adopted formula was

$$\mathrm{GSI} = \mathrm{GW}/\mathrm{TW} \times 100$$

where GW indicates gonad weight (g); TW, the total body weight (g); and GSI, the gonadosomatic index.

To relate the influence of the surface water temperature (SST °C) on the gonad development of fish during the study, data of monthly average SST were supplied by the Marine Ecology Section of the Marine Science and Fisheries Centre.

Relative Condition Factor (Kn)
The monthly Kn was calculated for the pooled samples of 2007–2008 and 2008–2009 using the formula of Le Cren (1951) as,

$$\mathrm{Kn} = \mathrm{TW}/aL^b$$

where TW represents the observed weight and aL^b the calculated weight from length-weight equation.

2.1.4 Fecundity

The fecundity of females was estimated gravimetrically (Jayabalan 1986; Zaki et al. 2016) from 22 ovaries in stage V.

The relationships between (1) total length and fecundity, (2) total body weight and fecundity and (3) ovary weight and fecundity were estimated by the least square method as,

$$F = aX^b$$

where F is the fecundity, a the constant, X the variable (fish length, fish weight or ovary weight) and b the regression coefficient.

2.1.5 Sex Ratio

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

2.2 Food Items and Feeding Intensity

For the general food composition of fish, the food items were identified up to generic/group level. The quantitative estimations of stomach contents were made

using points (volumetric) method (Hynes 1950). The food item in the advanced state of digestion was recorded as 'semidigested matter'. The pooled points gained by each food item were converted into respective percentage in the total points for the entire period of study.

To study the feeding intensity in fish, the fullness of the stomachs were grouped into actively fed (full and 3/4 full stomachs), moderately fed (1/2 full stomachs), poorly fed (1/4 full stomachs) and empty. The feeding intensity in relation to months, maturity stages and size of the fish was estimated.

3 Results and Discussion

3.1 Maturation and Spawning

3.1.1 Gonadosomatic Index

The monthly GSI values for 2007–2008 (Fig. 2) and 2008–2009 (Fig. 3) showed that the females recorded higher values than the males during all the months. The GSI indices were higher during March to May in 2007–2008 and April to July in 2008–2009 than the weighted averages which stood at 0.9182 and 1.5213 for males and 1.5789 and 2.6371 in females, respectively.

In Sohar region, the monthly SST ranged from 22.7 °C in August to 30.3 °C in October. The monthly SST was less than 24 °C during December to March and August. While the temperature progressively increased from March to June, the GSI values also increased in both the sexes. Similar trend occurred during both the years.

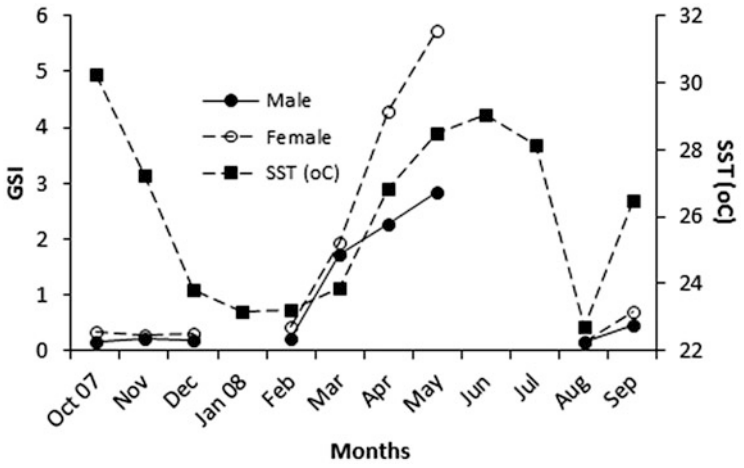

Fig. 2 Relationship between average monthly SST and GSI of *R. kanagurta* in Sohar during 2007–2008

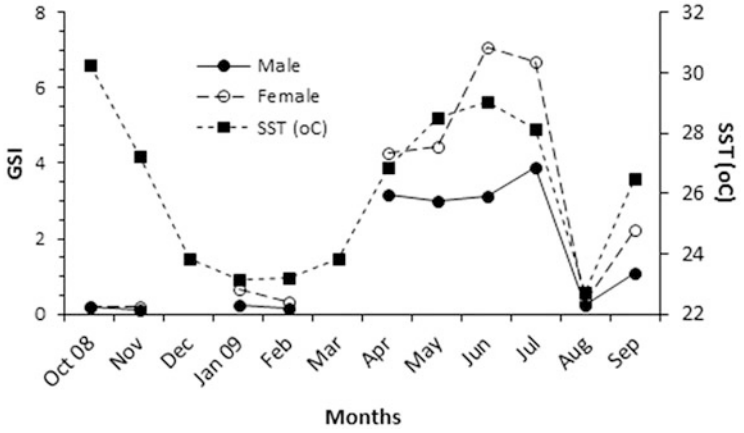

Fig. 3 Relationship between average monthly SST and GSI in *R. kanagurta* in Sohar during 2008–2009

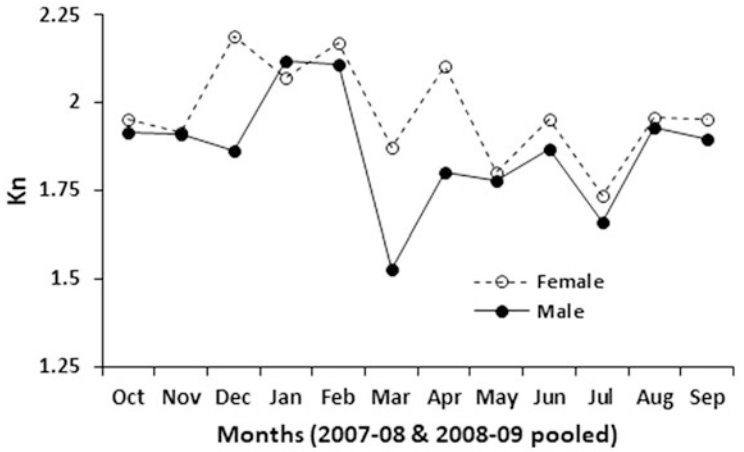

Fig. 4 Monthly Kn in *R. kanagurta* in Sohar during 2007–2009

3.1.2 Relative Condition Factor (Kn)

Generally, the monthly Kn values of females were higher than in males (Fig. 4), and the maximum values of males (2.1193) and females (2.1917) were recorded in January and December, respectively. The lowest Kn values were observed during March in males (1.5313) and July in females (1.737).

3.1.3 Spawning Season

The fish with mature gonads (stage V) occurred during March to May and spent individuals (stage VII) during May to October in 2007–2008 (Fig. 5). During 2008–2009, the spent gonads occurred from April to October (Fig. 6). This shows that *R. kanagurta* might spawn for 7 months from April to October in Sohar waters. There is flexibility in the spawning season of *R. kanagurta* in the coasts of Oman. Along the Muscat coast, the species had a single spawning season during 2008–2009 (September to February) and two spawning periods during 2007–2008 (September to February and May) (Zaki et al. 2011). However, the spawning period of the Indian mackerel from Mahout coast of Oman was found to be restricted to 4–6 months (Zaki et al. 2016). Indian mackerel spawns during different seasons along the Indian coasts (Chidambaram et al. 1952; Radhakrishnan 1962; Sekharan 1958; Rao 1967; Gopakumar et al. 1991; Yohannan and Abdurahiman 1998a); however, occurrence of mature fish is common almost the year-round along the Karnataka coast (Rohit and Gupta 2004). An appropriate water temperature and availability of food would trigger prolific spawning of the Indian mackerel (Yohannan and Abdurahiman 1998a).

3.1.4 Length at First Maturity

The smallest mature male and female fish were recorded in class interval of 191–200 mm (Fig. 7). The percentage maturity of males and females in various size groups indicated that the L_m was obtained at 228 mm in male and 232 mm in female along the Sohar coast. However, the L_m for males and females in the coast of Mahout was estimated at 252 and 257 mm, respectively (Zaki et al. 2016). This shows that the Indian mackerel in Oman matures earlier in the Sea of Oman than in the Arabian Sea.

From the Indian coasts bordering the Arabian Sea, the L_m of *R. kanagurta* ranged from 180 to 223 mm (Sekharan 1958; Rao 1967; Gopakumar et al. 1991; Yohannan and Abdurahiman 1998b; Rohit and Gupta 2004) and from the Bay of Bengal that varied between 182 and 188 mm (Abdussamad et al. 2006, 2010). However, from Seychelles, the L_m of fish was calculated at 205 mm (Sousa and Gislason 1985). Hence, the estimated values of L_m in the present study indicate that the fish would attain sexual maturity comparatively at a higher length in Omani waters than in the above coasts. The genetic analyses of the Indian mackerel distributed along the various coasts in the region would better explain the reason for the variations in the L_m of the species.

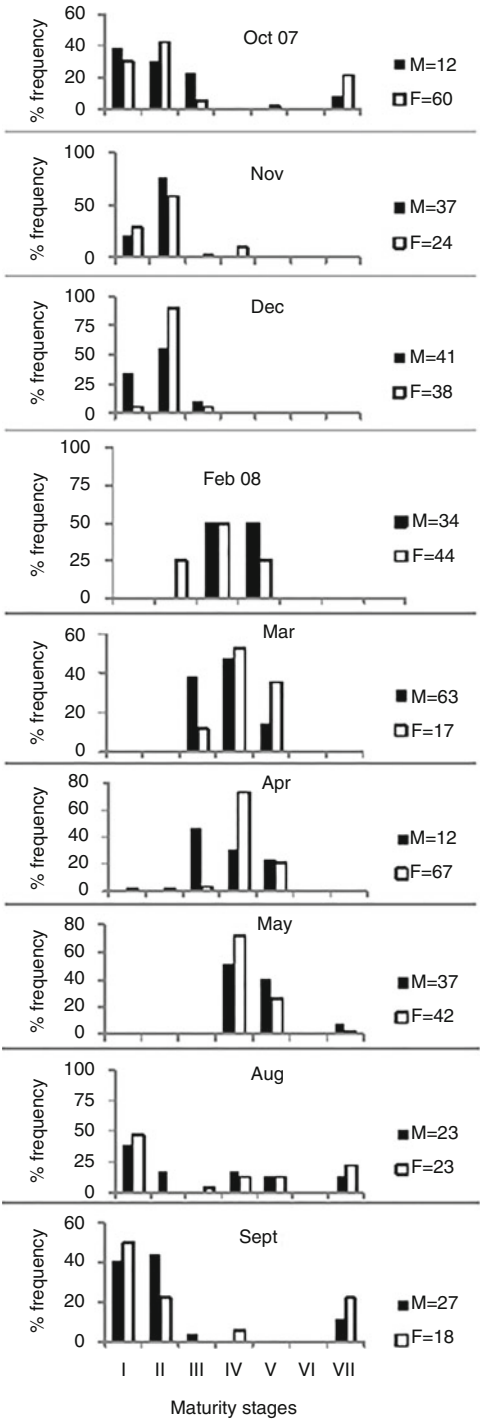

Fig. 5 Monthly maturity stages of *R. kanagurta* in Sohar during 2007–2008

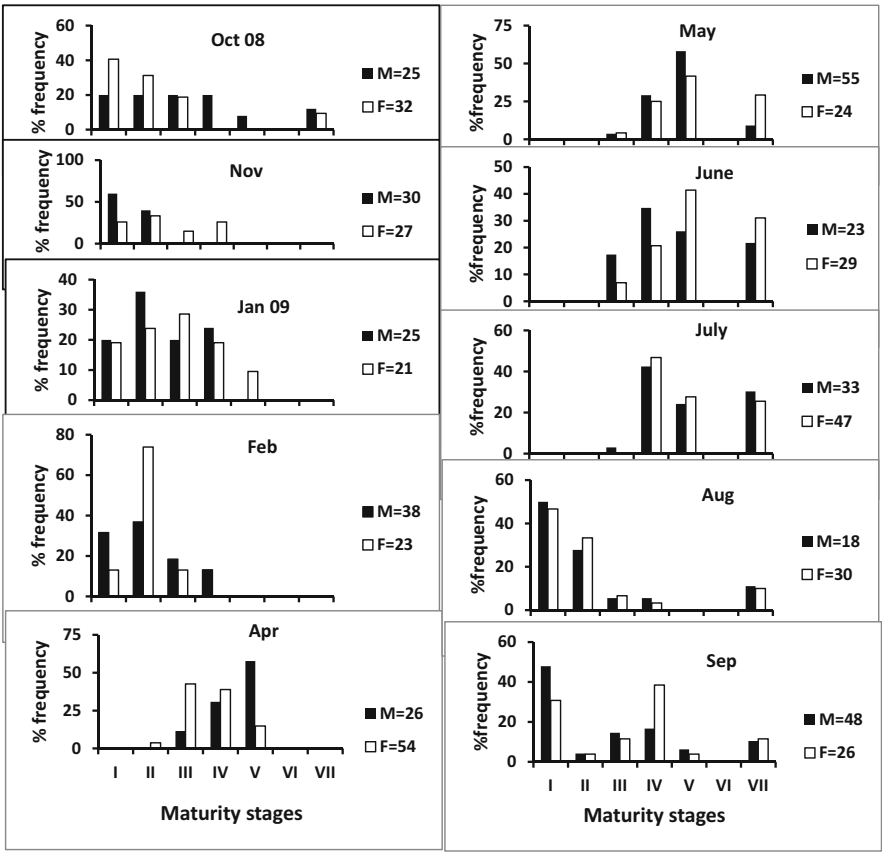

Fig. 6 Monthly maturity stages of *R. kanagurta* in Sohar during 2008–2009

3.1.5 Sex Ratio

The monthly male to female ratios during 2007–2008 were significantly different at 5% level in October, March and April (Table 1) and in April, May and September during 2008–2009 (Table 2). The overall annual sex ratios for 2007–2008 and 2008–2009 were 1:1.16 and 1:0.96, respectively, which indicated homogeneous distribution of sexes. However, an overall heterogeneous distribution of males and females of *R. kanagurta* was reported from Mahout in Oman (Zaki et al. 2016). Similar to variations in the sex ratios of *R. kanagurta* observed from Sohar and Mahout in Oman, both homogeneity in distribution of sexes from India (Gopakumar et al. 1991) and Pakistan (Moazzam et al. 2005) and heterogeneity in a study from India (Rohit et al. 1998) were recorded.

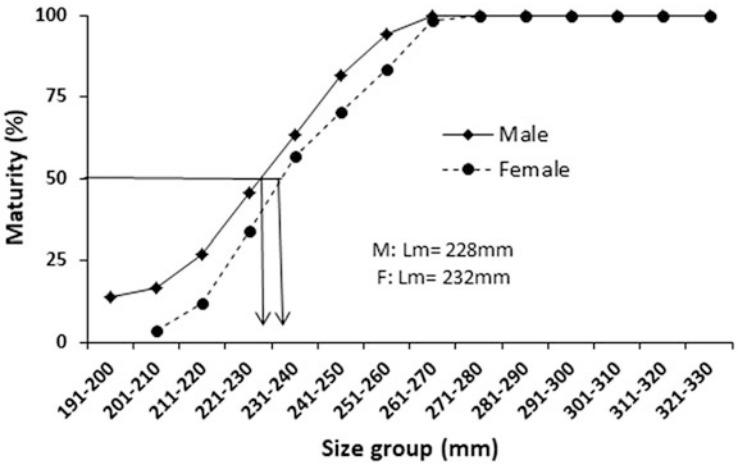

Fig. 7 Length at first maturity of *R. kanagurta* in Sohar

Table 1 Monthly sex ratio of *R. kanagurta* in Sohar during 2007–2008

Month	Male	Female	M:F	X^2 value	*P*-value
Oct 07	12	60	1:5.0	32.0*	1.54173E−08
Nov	37	24	1:0.65	2.77	0.096
Dec	41	38	1:0.93	0.1139	0.7357
Jan 08	No data				
Feb	34	44	1:1.29	1.282	0.2575
Mar	63	17	1:0.27	26.45*	2.70448E−07
Apr	12	67	1:5.58	38.29*	6.09387E−10
May	37	42	1:1.14	0.3164	0.5737
Jun	No data				
Jul	No data				
Aug	23	23	1:1.0		
Sep	27	18	1:0.67	1.80	0.1797
Total	286	333	1:1.16	3.5687	0.0588

*Significant at 5% level

3.1.6 Fecundity

The fecundity of *R. kanagurta* in Sohar varied from 55,614 eggs in a female of 23 cm TL, 138 g of total weight and 6.5 g of ovary weight to 133,728 eggs from the fish measuring 32 cm TL with 336 g total weight and 29.56 g of ovary weight (Table 3). The average fecundity in a female was estimated at 93,205 eggs.

The relationship between fecundity (F) and total length (TL) (Fig. 8a) can be expressed as,

Table 2 Monthly sex ratio of *R. kanagurta* in Sohar during 2008–2009

Month	Male	Female	M:F	X^2 value	*P*-value
Oct 08	25	32	1:1.28	0.8596	0.3538
Nov	30	27	1:0.9	0.15789	0.6911
Dec	No data				
Jan 09	25	21	1:0.84	0.3478	0.555
Feb	38	23	1:0.61	3.688	0.05478
Mar	No data				
Apr	26	54	1:2.08	9.8*	0.001745
May	57	22	1:0.39	15.506*	8.22295E−05
Jun	23	29	1:1.26	0.692	0.405
Jul	33	47	1:1.42	2.45	0.1175
Aug	18	30	1:1.67	3	0.0832
Sep	48	26	1:0.54	6.5405*	0.0105
Total	323	311	1:0.96	0.2271	0.6336605

*Significant at 5% level

Table 3 Fecundity of *R. kanagurta* in Sohar

S. no.	Total length (cm)	Total weight (g)	Ovary weight (g)	Fecundity
1	23	138	6.5	55,614
2	24.5	186	9.82	67,146
3	25.9	204	8.9	62,016
4	26	218	14.59	84,366
5	26.5	246	7.58	82,164
6	26.9	226	12.15	64,862
7	27	228	17.38	85,728
8	27.5	248	10.03	68,448
9	27.5	246	15.1	95,202
10	27.8	230	21.3	109,480
11	28	294	13.02	102,018
12	28	296	11.6	87,912
13	28.2	244	21.94	97,112
14	28.8	272	26.11	104,992
15	28.9	272	24.59	99,824
16	29	284	24.21	118,996
17	29.3	236	21.62	99,356
18	29.5	298	20.25	118,604
19	30	300	20.02	112,500
20	30.5	314	26.54	94,828
21	31.2	324	28.79	105,624
22	32	336	29.56	133,728

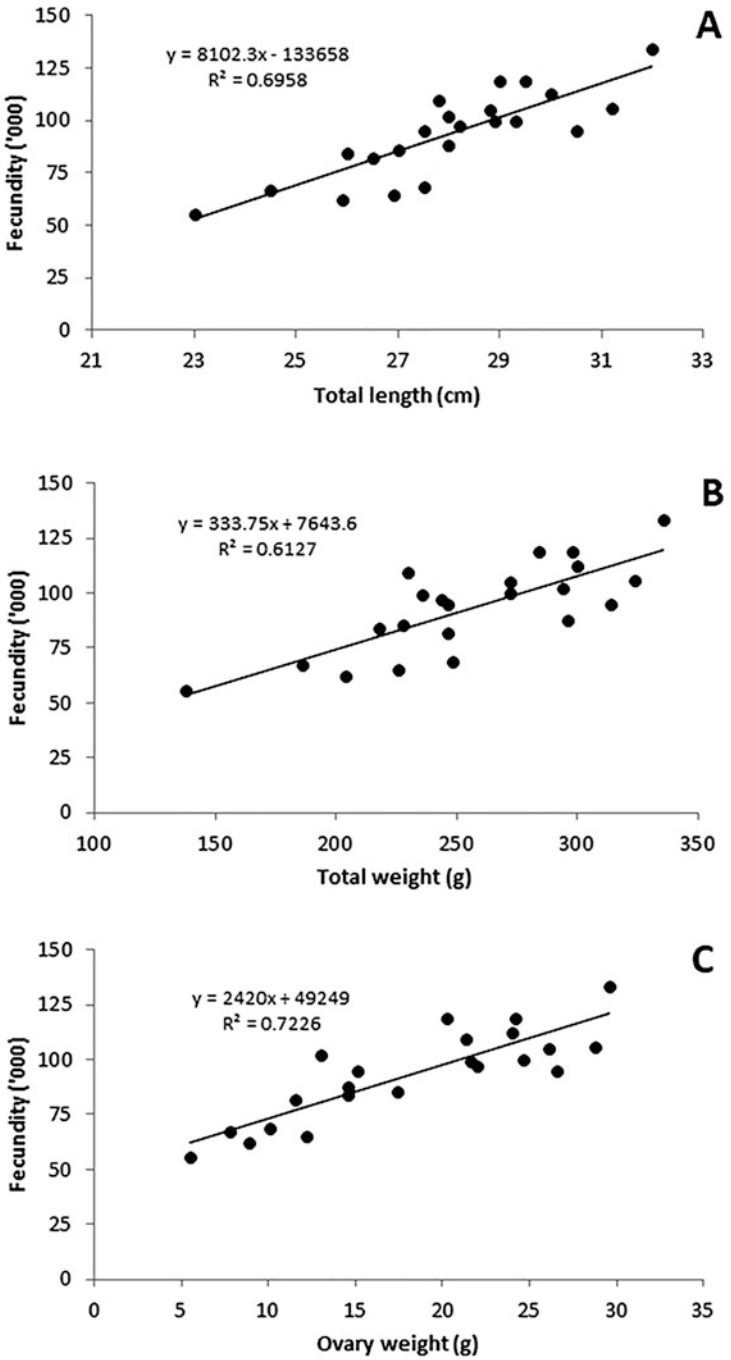

Fig. 8 Relationships between fecundity and (**a**) total length, (**b**) total weight and (**c**) ovary weight of *R. kanagurta* in Sohar

$$F = 8102.3\text{TL} - 133658 \left(R^2 = 0.6958\right)$$

The expression for fecundity (F) in relation to total weight of fish (Tw) (Fig. 8b) was

$$F = 333.75\text{Tw} + 7643.6 \left(R^2 = 0.6127\right)$$

The relationship between the fecundity (F) and ovary weight (Ow) (Fig. 8c) was found to be

$$F = 2420\text{Ow} + 49249 \left(R^2 = 0.7226\right)$$

The estimated fecundity of the Indian mackerel indicated better correlation with ovary weight ($R^2 = 0.7226$) than total length and total weight of fish. While fecundity of the fish along the coasts of India varied between 20,911 and 123,000 eggs (Devanesan and John 1940; Rao 1967; Gopakumar et al. 1991; Abdussamad et al. 2010), a higher fecundity range (55,614–133,728 eggs) was observed in Sohar. The size of *R. kanagurta* in commercial catches of Sohar ranged from 121 to 340 mm TL, and the average length at capture (L_c) was calculated at 233 mm TL (Zaki et al. 2011). As the L_m is almost close to L_c along the Sohar coast, management measures are needed to regulate the legal size of the fish.

3.2 Food and Feeding Habits

3.2.1 General Food Composition

The food items of *R. kanagurta* in Sohar region consisted of copepods (36.6%), diatoms (9.2%), dinoflagellates (3.8%), crustacean remains (7.2%), fish eggs (2.3%), molluscan larvae (1.7%) and semidigested matter (39.2%) (Fig. 9). The results confirm that the fish is a plankton feeder preferring mainly the zooplankton.

3.2.2 Feeding Intensity

Monthly Variation in Feeding Intensity

During 2007–2008, active feeding in *R. kanagurta* was observed from October to February and again in April (Fig. 10). While moderate feeding occurred during March and September, poor feeding was recorded in less number of fish during all the months.

Higher percentages of fish during 2008–2009 fed actively in October to January and April (Fig. 11). During February, July and September, moderate feeding was

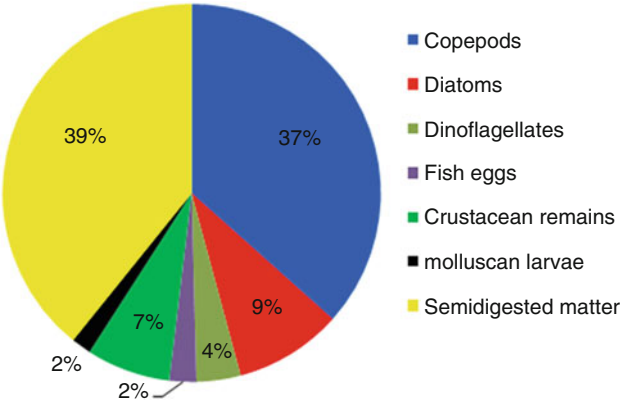

Fig. 9 General food composition of *R. kanagurta* in Sohar

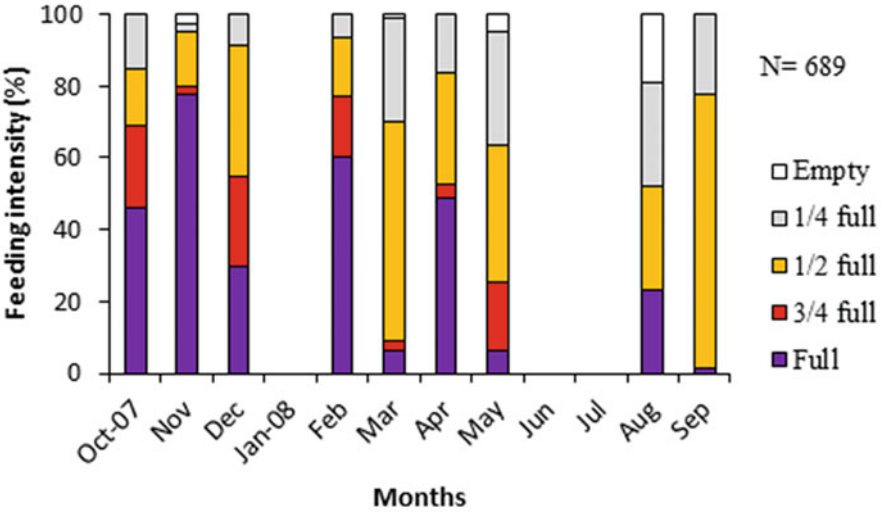

Fig. 10 Feeding intensity in *R. kanagurta* during various months in Sohar (2007–2008)

common nearly in 79% of stomachs occurred with poor feeding intensity during June 2009.

Feeding Intensity in Relation to Size

Feeding intensity of Indian mackerel from Sohar indicated that moderate feeding (1/2 full stomachs) was most common in different size groups both during 2007–2008 (Fig. 12) and 2008–2009 (Fig. 13). More number of empty stomachs occurred during 2008–2009 than in 2007–2008 in all the size groups.

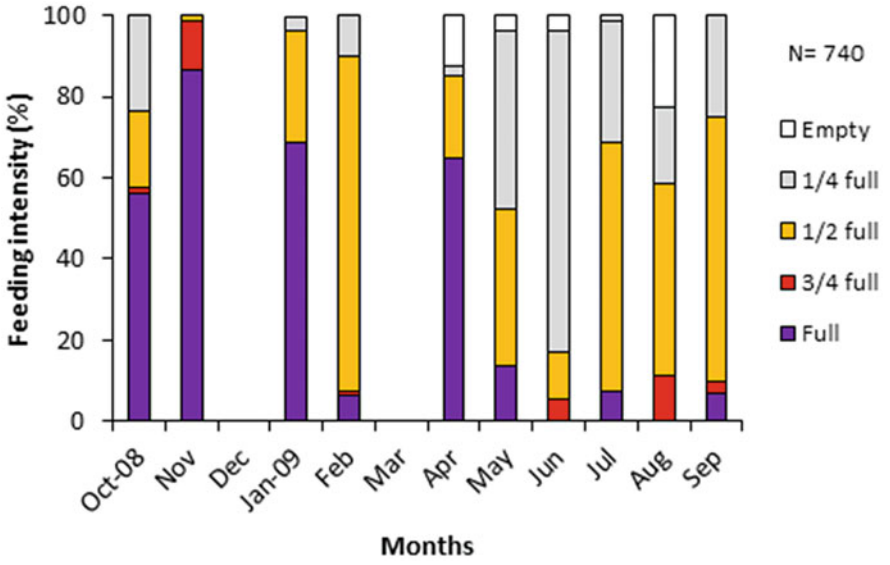

Fig. 11 Feeding intensity in *R. kanagurta* during various months in Sohar (2008–2009)

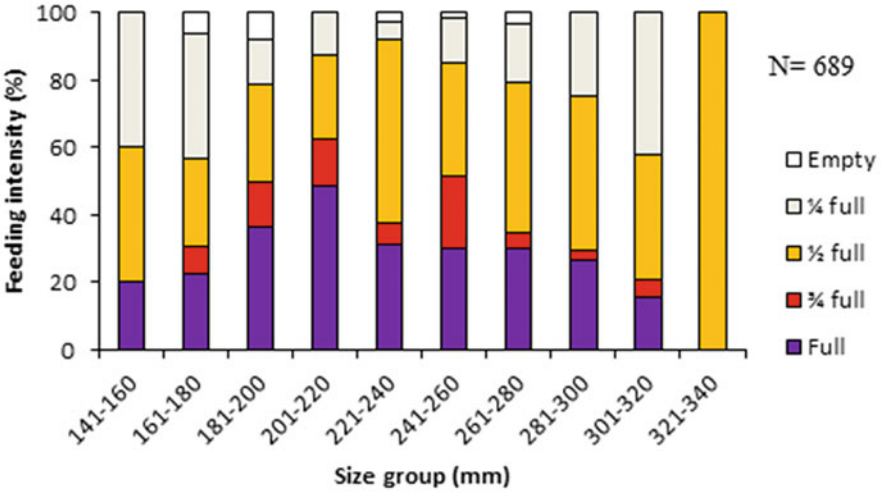

Fig. 12 Feeding intensity in different size groups of *R. kanagurta* in Sohar (2007–2008)

Feeding Intensity in Relation to Maturity Stages

Spent fish of both the sexes are fed voraciously than the individuals in other stages of maturity during 2007–2008 (Fig. 14) and 2008–2009 (Fig. 15). Higher percentages of fish in advanced stages of maturity (stages IV and V) generally had either moderate or poor feeding condition. Fish with empty stomachs occurred in lesser

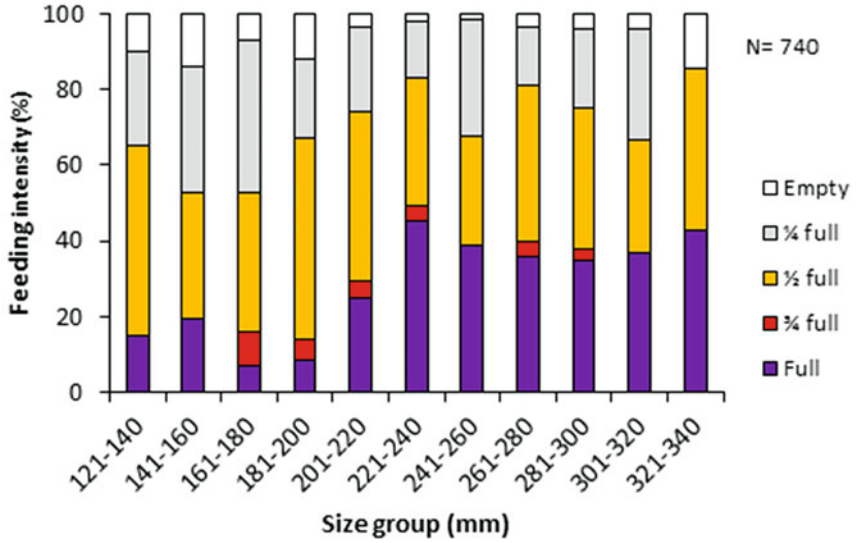

Fig. 13 Feeding intensity in different size groups of *R. kanagurta* in Sohar (2008–2009)

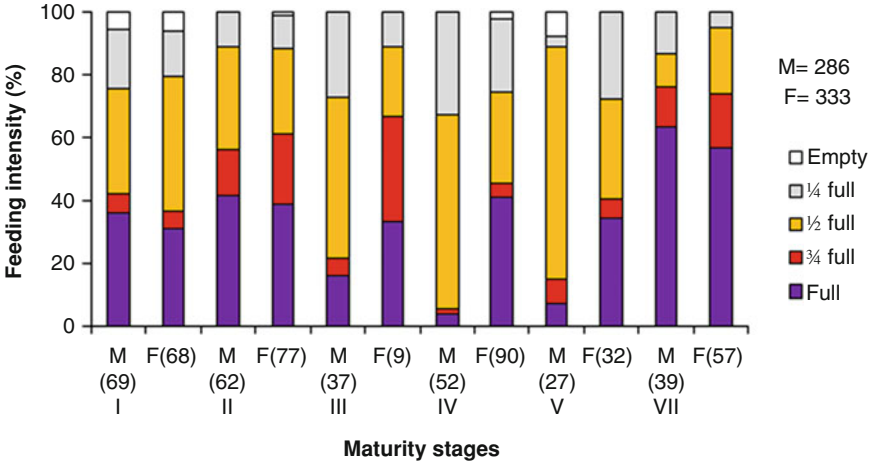

Fig. 14 Feeding intensity in relation to maturity stages of *R. kanagurta* in Sohar during 2007–2008

percentages in stages I, II, IV and V during 2007–2008 and in stages IV and V during 2008–2009.

The Indian mackerel is primarily a plankton feeder preferring both the phyto- and zooplankton (Chacko 1949; Bhimachar and George 1952; Venkataraman 1961; Rao 1962; Sivadas and Bhaskaran 2009). As the fish feeds on both plant and animal matter, it is considered as an omnivore. The present study also confirmed the

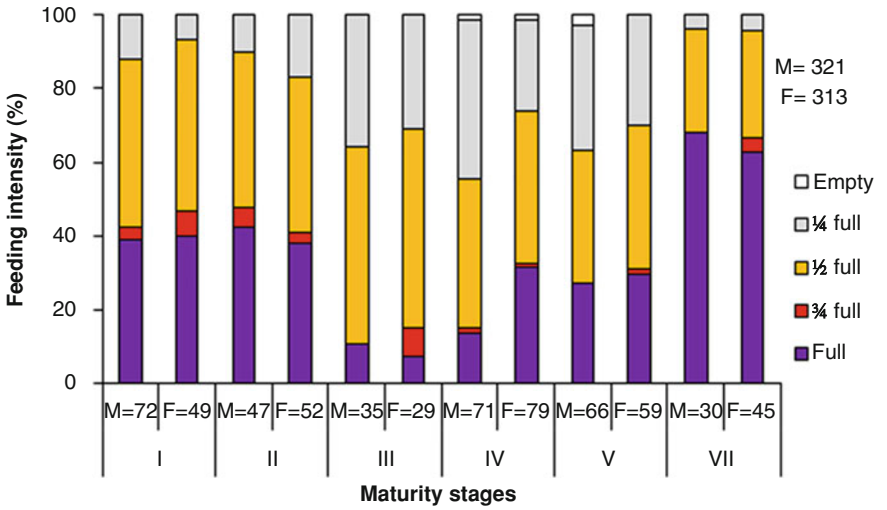

Fig. 15 Feeding intensity in relation to maturity stages of *R. kanagurta* in Sohar during 2008–2009

omnivorous feeding habit of fish feeding primarily on copepods followed by diatoms, crustacean remains, dinoflagellates, fish eggs and molluscan larvae. As the plankton feeder, Indian mackerel plays significant role in utilizing the primary and secondary production in the coastal waters and sustains effective link in the food chain with larger carnivores (Yohannan and Sivadas 2003).

The fish in advanced stages of maturity (stages IV and V) were recorded with moderate or poor feeding condition. This is in agreement with the earlier studies (Bhimachar and George 1952; Venkataraman 1961; Rao 1962; Noble 1962). The feeding behaviour of the fish is influenced by the prey availability (Dorner et al. 2003) and seasonal variation in the zooplankton assemblage or coexisting other prey fishes in the environment (Persson and Bronmark 2002; Galarowicz et al. 2006). The dominance of copepods in the stomach contents of fish in the present investigation may be due to their availability as the dominant food item in the Sea of Oman. Fish with empty stomachs occurred in different months and sizes and maturity condition of fish; however, active feeding was found in spent fish.

Acknowledgements We are very much thankful to H. E. Dr. Hamed Al-Oufi, the Undersecretary of Fisheries Wealth, and Dr. Saoud Al-Habsi, the Director General of Fisheries Research, Ministry of Agriculture and Fisheries Wealth, Government of Sultanate of Oman, for their keen interest in the study and encouragement. Our sincere thanks are due to Agriculture and Fisheries Development Fund (AFDF), Government of Sultanate of Oman, for funding support. We also thank the project colleagues for their technical help.

References

Abdussamad EM, Kasim HM, Achayya P (2006) Fishery and population characteristics of Indian mackerel, *Rastrelliger kanagurta* (Cuvier) at Kakinada. Indian J Fish 53(1):77–83

Abdussamad EM, Pillai NGK, Kasim HM, Habeeb Mohamed OMM, Jeyabalan K (2010) Fishery, biology and population characteristics of Indian mackerel, *Rastrelliger kanagurta* (Cuvier) exploited along the Tuticorin coast. Indian J Fish 57(1):17–21

Al-Abdessalaam TZS (1995) Marine species of the Sultanate of Oman. Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries, Sultanate of Oman, Publication No. 46/95, 412 p

Bhimachar BS, George PC (1952) Observations on the food and feeding of the Indian mackerel *Rastrelliger kanagurta* (Cuvier). Pro Indian Acad Sci 36(3):105–118

Chacko PI (1949) Food and feeding habits of the fishes of the Gulf of Mannar. Proc Indian Acad Sci 29B(3):83–97

Chidambaram K, Krishnamurthy CG, Venkataraman R, Chari ST (1952) Studies on mackerel: fat variation and certain biological aspects. Proc Indian Acad Sci 35B(2):43–68

Collette BB, Nauen CE (1983) FAO species catalogue, Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fish Synop 125(2):137 p

Devanesan DW, John V (1940) On the natural history of *Rastrelliger kanagurta* (Russell) with special reference to its spawning season and eggs. Curr Sci 9(10):462–464

Dorner H, Berg S, Jacobsen L, Hulsmann S, Brojerg M, Wagner A (2003) The feeding behavior of large perch *Perca fluviatilis* (L.) in relation to food availability: a comparative study. Hydrobiologia 506(1):427–434

Fischer W, Bianchi G (eds) (1984) FAO species identification sheets for fishery purposes, Western Indian Ocean (fishery area 51). Food and Agricultural Organisation of the United Nations, Rome

Fischer W, Whitehead PJP (eds) (1974) FAO species identification sheets for fishery purposes. Eastern Indian Ocean (fishing area 57) and Western Central Pacific (fishing area 71). Food and Agricultural Organisation of the United Nations, Rome

Galarowicz TL, Adams JA, Wahl DH (2006) The influence of prey availability on ontogenetic diet shifts of a juvenile piscivore. Can J Fish Aquat Sci 63(8):1722–1733

Gopakumar G, Pillai NGK, Omana TA (1991) The fishery characteristics and biology of mackerel at Vizhinjam. J Mar Biol Ass India 33(1&2):107–114

GoSO (Government of Sultanate of Oman) (2009) Fishery statistics book 2009. Fisheries Statistics and Information Dept., Directorate General of Fisheries Research, Oman

Hynes HBN (1950) The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*) with a review of methods used in the studies of food of fishes. J Anim Ecol 19:36–58

Jayabalan N (1986) Reproductive biology of the silverbelly *Leiognathus splendens* (Cuvier) at Porto Novo. Indian J Fish 33(2):171–179

Jayabalan N, Zaki S, Al-Kiyumi F, Al-Kharusi L, Al-Habsi S (2014) Age, growth and stock assessment of the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1817) along the Sohar coast of Oman. Indian J Fish 61(1):1–6

Le Cren ED (1951) Length-weight relationship and seasonal cycle in gonad weight and condition of perch (*Perca fluviatilis*). J Anim Ecol 20:201–219

Moazzam M, Osmany HB, Zohra K (2005) Indian mackerel (*Rastrelliger kanagurta*) from Pakistan-I. Some aspects of biology and fisheries. Rec Zool Surv Pak 16:58–75

Noble A (1962) The food and feeding habits of the Indian mackerel *Rastrelliger kanagurta* (Cuvier) at Karwar. Indian J Fish 9A(2):701–713

Persson A, Bronmark C (2002) Foraging capacity and resource synchronization in an ontogenetic diet switcher, Pike perch (*Stizostedion lucioperca*). Ecology 83(11):3014–3022

Pradhan LB, Palekar VC (1956) Key to the stages of sexual maturity of *Rastrelliger kanagurta* (Cuv.). Indian J Fish 3(1):183–185

Radhakrishnan N (1962) Observations on the maturity and spawning of Indian mackerel, *Rastrelliger kanagurta* (Cuvier) at Karwar. Indian J Fish 9A(2):512–524

Randall JE (1995) Coastal fishes of Oman. University of Hawaii Press, Honolulu, HI, p 439

Rao KVN (1962) Food of the Indian mackerel *Rastrelliger kanagurta* (Cuvier) taken by drift nets in the Arabian Sea off Vizhinjam, South Kerala. Indian J Fish 9A(2):530–541

Rao VR (1967) Spawning behaviour and fecundity of Indian mackerel *Rastrelliger kanagurta* (Cuvier) at Mangalore. Indian J Fish 14(1&2):171–186

Rohit P, Gupta AC (2004) Fishery, biology and stock of the Indian mackerel *Rastrelliger kanagurta* off Mangalore-Malpe in Karnataka, India. J Mar Biol Assoc India 46(2):185–191

Rohit P, Pillai PP, Gupta AC, Preetha K (1998) Fishery and population characteristics of mackerel landed by trawlers along the Dakshina Kannada coast. Indian J Fish 45(1):21–27

Sekharan KV (1958) On the South Kanara coastal fishery for mackerel together with notes on the biology of the fish. Indian J Fish 5(1):1–31

Sivadas M, Bhaskaran MM (2009) Stomach content analysis of the Indian mackerel *Rastrelliger kanagurta* (Cuvier) from Calicut, Kerala. Indian J Fish 56(2):143–146

Sousa MI, Gislason H (1985) Reproduction, age and growth of the Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816) from Sofala Bank, Mozambique. Rev de Inv Pesq 14:1–28

Venkataraman G (1961) Studies on the food and feeding relationships of the inshore fishes off Calicut on the Malabar coast. Indian J Fish 7(2):275–306

Yohannan TM, Abdurahiman UC (1998a) Environmental influence on the behaviour of Indian mackerel and their availability to fishing gear along the Malabar coast. Indian J Fish 45 (3):239–247

Yohannan TM, Abdurahiman UC (1998b) Maturation and spawning of Indian mackerel. Indian J Fish 45(4):399–406

Yohannan TM, Sivadas M (2003) The Indian mackerel. In: Mohan Joseph M, Jayaprakash AA (eds) Status of exploited marine fishery resources of India. CMFRI, Cochin, pp 60–65

Zaki S, Jayabalan N, Al-Kiyumi F, Al-Kharusi L, Al-Habsi S, Al-Marzouqi A (2011) Fishery, biology and population dynamics of three small pelagic fish species (Indian oilsardine *Sardinella longiceps*, Indian mackerel *Rastrelliger kanagurta* and Indian scad *Decapterus russelli*) from the Sultanate of Oman. Project Final Report-Part II. Ministry of Agriculture and Fisheries, Oman, 163 p

Zaki S, Jayabalan N, Al-Kiyumi F, Al-Kharusi L (2016) Reproductive biology of the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1816) from the Mahout coast, Sultanate of Oman. Indian J Fish 63(2):24–32