RESEARCH ARTICLE

Reproductive Biology of the Indian Oil Sardine Sardinella longiceps From Al-Seeb Waters off Oman

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Reproductive Biology of the Indian Oil Sardine *Sardinella longiceps* From Al-Seeb Waters off Oman

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Abstract
The objective of this study is to examine the reproductive biology of the Omani-Indian oil sardine *Sardinella longiceps* from Al-Seeb area off the Omani waters. During the period January 2004–December 2008, a total of 1592 sardines were sampled. The lengths of the sampled fish ranged from 11.9 to 22 cm with a mean length of 16.5 ± 1.84 cm and modal length of 15.5 cm. Their weights ranged from 14 to 94.6 g with a mean weight of 42.43 ±15.19 g and modal weight of 43.7 g. The length–weight relationship equations analyzed for the combined sex, female, and male sardines were $W = 0.009 \times L^{2.99}$, $W = 0.011 \times L^{2.94}$, and $W = 0.001 \times L^{2.94}$, respectively. The length at 50% maturity for combined sex, female, and male sardines was 16.35, 16.46, and 16.28 cm, respectively. During the study, the Omani sardines were observed to spawn in October, June, and July, September, June, and January and September during the years 2004, 2005, 2006, 2007, and 2008, respectively. During the sampling period, the relative condition factor K_n varied from one year to another and ranged from 0.36 to 1.46 with a mean of 0.9 ± 0.08. An overall mean sex ratio of 0.68 ± 0.02 proved to be significantly different from the expected theoretical sex ratio of 0.5 (χ^2 = 200; df = 1; $P < 0.05$).

Keywords: Oman; Indian oil Sardine; biology.

1. Introduction

The Indian oil sardine *Sardinella longiceps* is considered to be an important small pelagic fish for the traditional Omani fishermen along the Omani coast (Figure 1). Sardines along the Omani coast are harvested mainly by beach seines, gill nets, and occasionally by cast nets. The sardine landings for the period 2002–2009 were reported to be stable and never significantly changed from the average of 34,673 mt (Figure 2). The small pelagic coastal traditional fishery in Oman includes sardines, Indian mackerel, anchovies, small jacks, mullets, needle fish, and "other small pelagics" (a mixture of different small pelagics). During the period 1994–2007, sardines contributed to 76% of the total small pelagic landings and 51% to the total values [1].

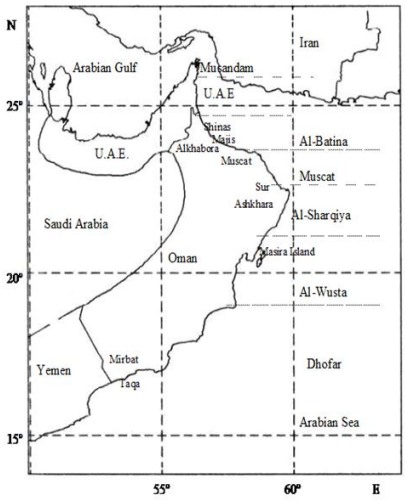


Figure 1: Map of Oman showing the regions.

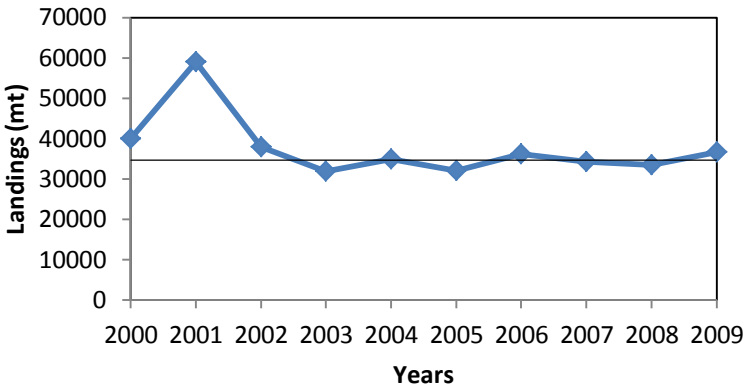


Figure 2: Total landings of Omani-Indian oil sardine during 2000–2009.

Beach seines and purse seines are modified gill nets that require up to 12 people to set and haul. Fishermen can catch about 30–40 tons of sardines in a day when they are abundant. In general, beach seines are the most common type of gears used for catching sardines [2]. The Omani *S. longiceps* is a batch-fecund multiple spawner and the available studies on the gonadosomatic index (GSI) of the fish indicate that sardines in Oman spawn during March, August, and February [1], and April and October [3–5]. The length at 50% maturity ranged between 150 and 174 mm total length for the combined sex, female, and male sardines [5].

The aim of this paper is to further study the reproduction of *S. longiceps* in Oman. The analysis included determination of spawning season, length–weight relationship, sex ratio, length at 50% maturity, and relative condition factor of the fish. The results of this study will help in building up and compiling information and database needed for stock assessment, management, and development of the Omani sardine's stock parameters.

2. Methods

Sardines were collected regularly and randomly from Al-Seeb landing site, which is considered to be one of the active fish markets along the Omani coast line. A total of 1592 sardines were collected during the sampling period January 2004–December 2008. For further analysis, fish samples were put in cool box with ice flakes and transported to the Department of Marine Science and Fisheries laboratory at the Sultan Qaboos University, which is 20 min away from the landing site. The cool box temperature was maintained at 20–23°C. Thereupon, the sardines were at once analyzed for total length to nearest 0.1 cm accuracy measuring from the tip of the mouth to the longest lobe of the caudal fin. Weight of the fish and gonads were also recorded to the nearest 0.01 g using an electronic balance (Mettler PE 360). Furthermore, the samples were analyzed for sex and maturity stages visually. Five maturity stages were allocated based on shape, color, and appearance of gonads [6]. For each sex, the maturity stages were grouped into immature (stages I and II), maturing (stage III), mature (stages IV and V), and spent.

The length–weight relationship was determined for the male (n = 487), female (n = 1022), and combined sex samples (n = 1592) by the exponential equation $W = a\mathrm{TL}^b$ [7], where W is the weight of the fish in grams, TL the total length of the fish in cm, and variables "a" and "b" the regression coefficients. The relative condition factor (K_n) of the fish was determined by the equation $K_n = \frac{W}{\mathrm{TL}^3} \times 100$ [8]. Sex ratios were expressed as the total number of females to the sum of total number of males and females. The χ^2-test was used to test whether the sex ratio was different from the expected and theoretical sex ratio of 0.5. The GSI was estimated as (gonad weight/total fish weight) × 100 [9]. The length at 50% maturity for the male (n = 464), female (n = 846), and combined sex sardines (n = 1367) was estimated by applying the cumulative frequency (f, %).

3. Results

3.1. Population structure

A total of 1592 sardines were sampled during the study period. The total length of the sardines ranged from 11.9 to 22.0 cm with a mean length of 16.5 ± 1.84 cm and modal length of 15.5 cm. The smallest sardine (unsexed) was sampled from the October 2008 samples and the largest (female) was sampled in January 2004 and April

2007. A total of 1022 (68%) female and 487 (32%) male sardines were sampled during this study (Figure 3). The minimum number of sardines were sampled in 2006 (females = 135 and males = 66) and all the maturity stages were present during this sampling period (Figure 4a and b) (Figure 5). The male sardines ranged from 12.3 to 21.5 cm with a mean length of 16.4 ±1.8 cm, while the female sardines ranged from 12.8 to 22.0 cm with a mean of 16.7 ± 1.72 cm. The female sardines were found to be longer than the male sardines. On the other hand, the total weight of the sardines ranged from 14.0 to 94.6 g with a mean weight of 42.43 ± 15.19 g and modal weight of 43.7 g. Weights of female sardines ranged from 16.8 to 94.6 g, while for the males it ranged from 19.5 to 90.6 g. The female sardines were found to be heavier (mean 43.65 ± 14.83 g) than the male sardines (mean 41.55 ± 14.62 g). The results indicated a significant difference between the male and female lengths (t = –2.87; df = 918; P = 0.00042). On the other hand, the weights of males and females were statistically proved to have no significant difference (t = 1.26; df = 963; P = 0.1).

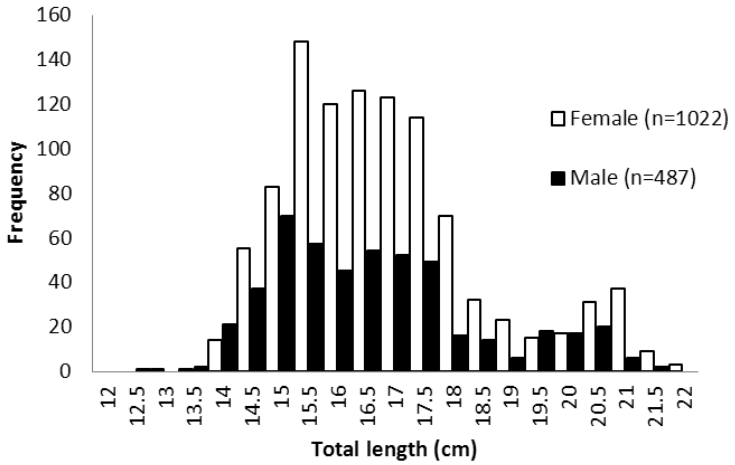


Figure 3: Length frequency distribution of the Omani-Indian oil sardine *S. longiceps*.

3.2. Sex ratio

A total of 1514 sardines were identified based on sex, the female-to-male sex ratio obtained was: 0.68 for the entire sample; 0.68 for the 2004 (n = 367); 0.7 for the 2005 (n = 350); 0.67 for the 2006 (n = 201); 0.63 for the 2007 (n = 393); and 0.72 for the 2008 (n = 279) samples. An overall mean sex ratio of 0.68 ± 0.02 proved to be significantly different from the expected theoretical sex ratio of 0.5 (χ^2 = 200; df = 1; $P < 0.05$). Monthly sex ratio ranged from 0.29 in January 2007 to 0.98 in April 2008. In general, the monthly sex ratio favored the females except in months January, October, and August when the values were 0.29, 0.48, and 0.45, respectively (Figure 6). On the other hand, the percentage of occurrence of females was almost higher than the males in all length classes except in 13- to 14-cm and 19.5- to 19.9-cm length classes (Figure 7).

3.3. Length–weight relationship and length at 50% maturity

A total of 846 females and 336 males ranging in total length from 12.8 to 22.0 cm and 12.3 to 21.5 cm, respectively, were used to estimate the length at 50% maturity. The results of the cumulative frequency analysis (%f) indicated that the length at 50% maturity was 16.35 cm for the combined sexes, 16.46 cm for the females, and 16.28 cm for the males (Figure 8). The smallest mature specimen was a 13.4-cm male sardine weighing 22 g.

From the length–weight data analysis the following relationships were obtained: $W = 0.009 \times L^{2.99}$ for the combined sex (n = 1592 and r = 0.96) as shown in Figure 9a, $W = 0.011 \times L^{2.94}$ for female (n = 1022 and r = 0.97) as in Figure 9b, and $W = 0.001 \times L^{2.94}$ (n = 487 and r = 0.97) as in Figure 9c for male sardines. There was no statistically significant difference between the calculated b-value (b = 2.99) and the expected b-value (b = 3) (t = 0.514; df = 1590; $P < 0.05$) for the combined sexes. On the other hand, the results indicated a significant difference between the expected b-value and the calculated b-values for different sexes, that is it was (b = 2.94) (t = 2.4; df = 11020; $P > 0.05$) for females and 2.94 (t = 1.95; df = 485; $P > 0.05$) for males.

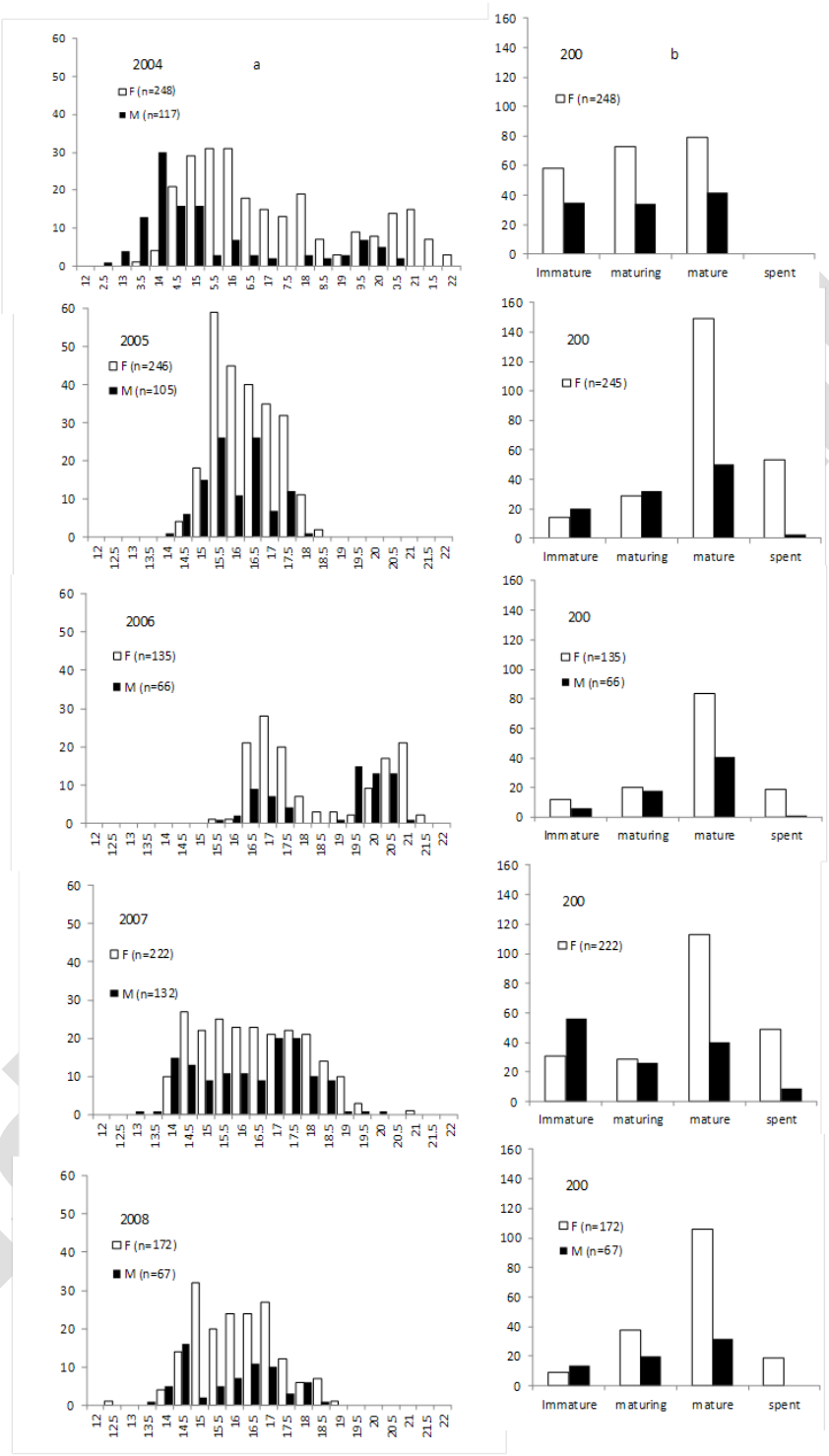
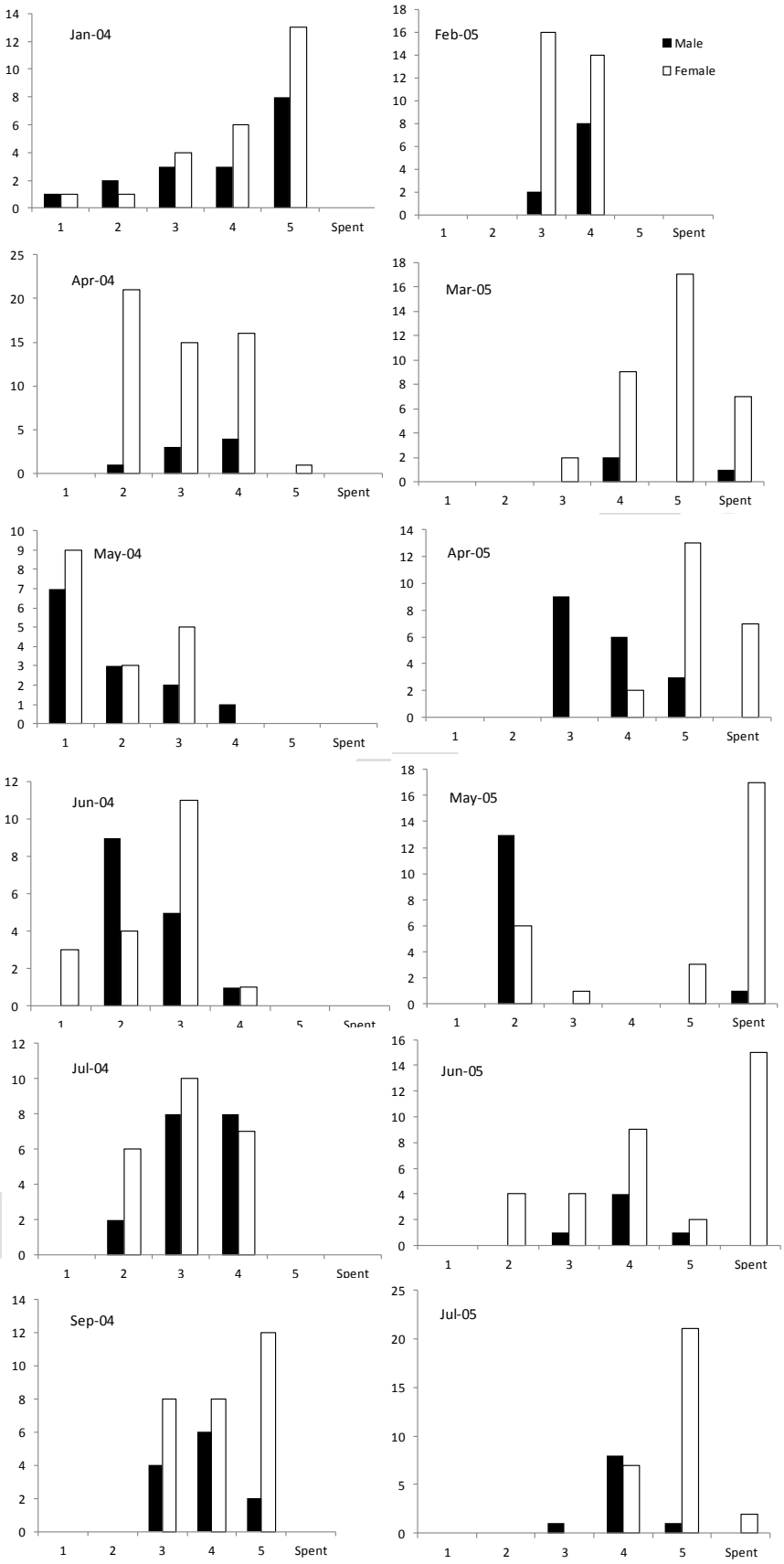


Figure 4: Monthly frequency distribution of the Omani-Indian oil sardine (*Sardinella longiceps*) by sex for samples collected from Al-Seeb area, Oman (January 2004–December 2008). (a) Total length (mm) and (b) Maturity stages.


Jan-04
Feb-05
Male
Female
Apr-04
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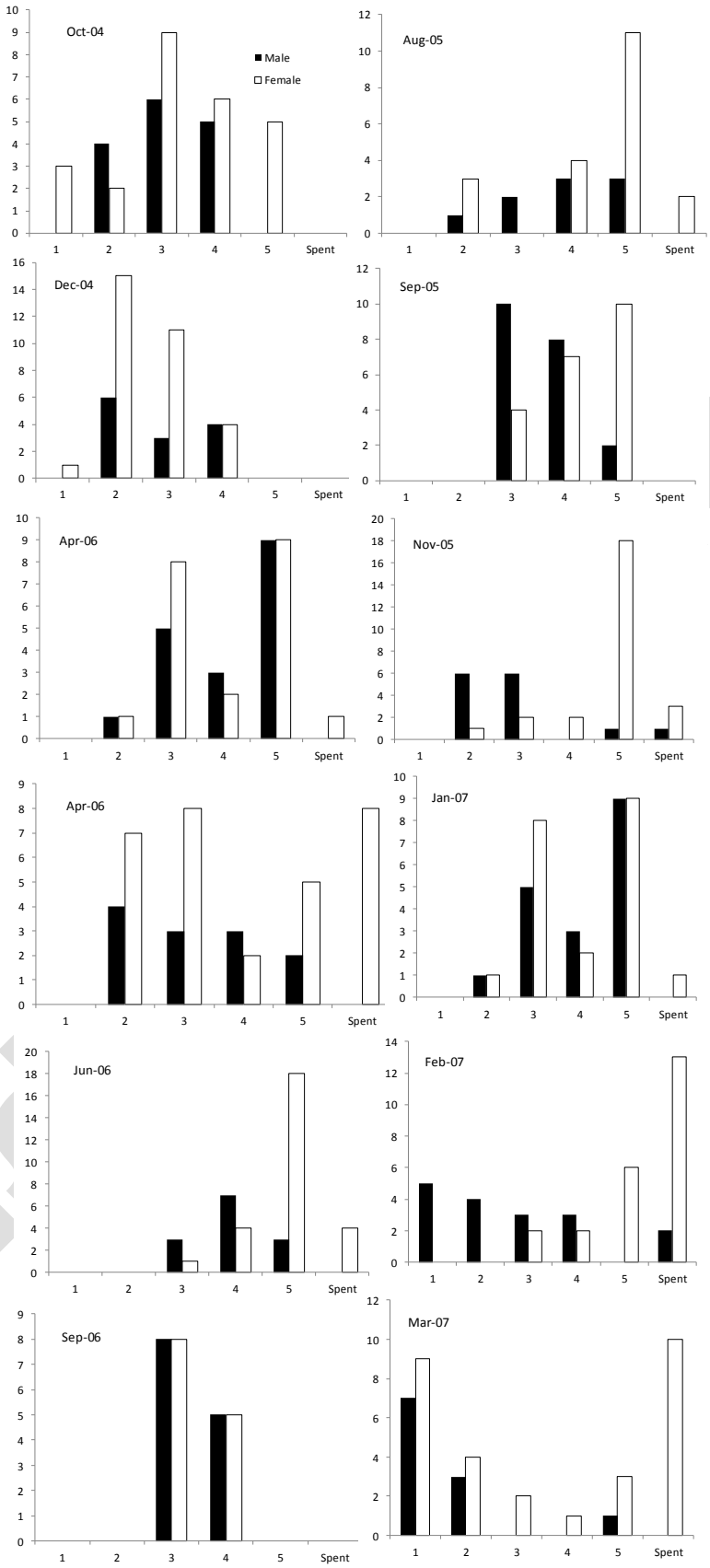
Spent


Oct-04
Male
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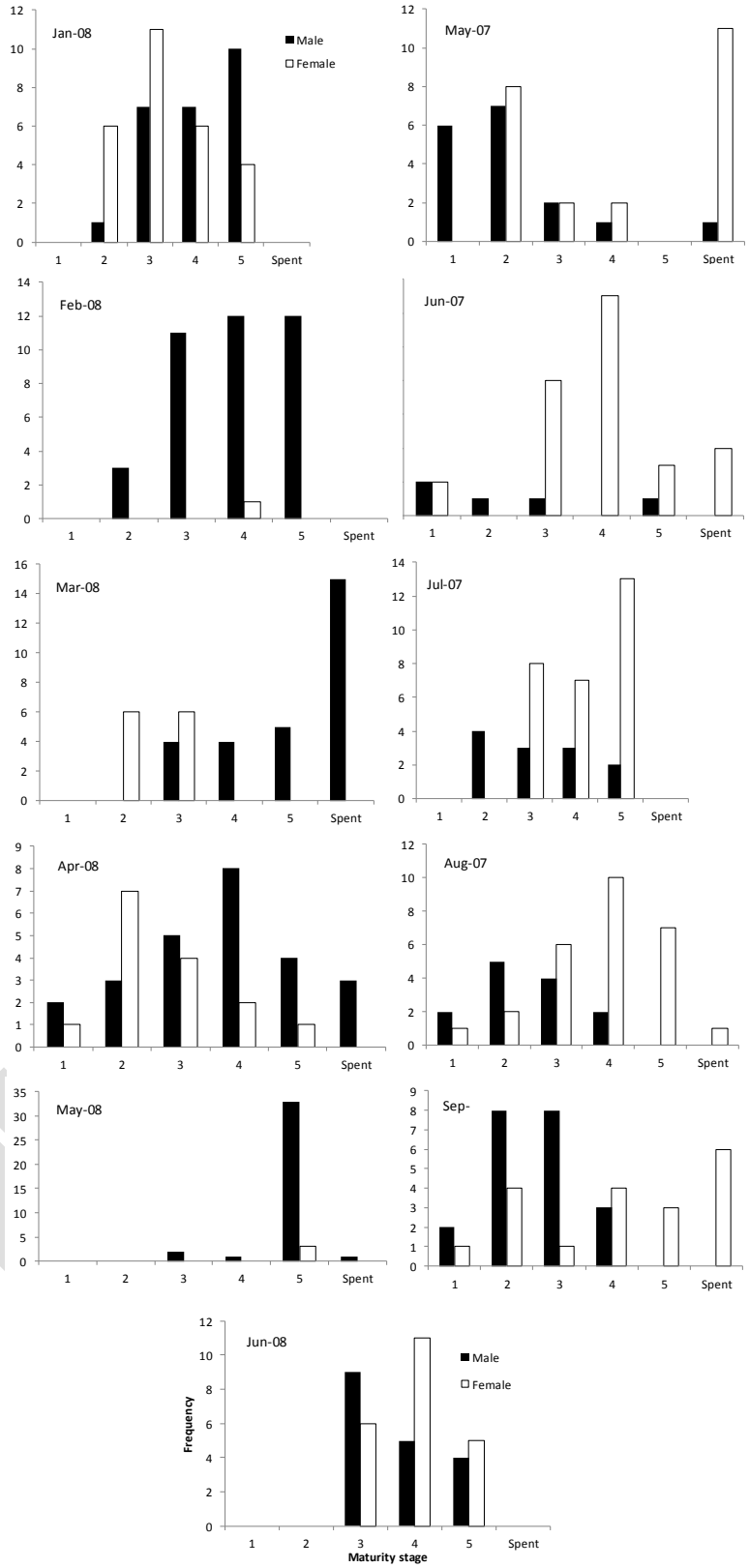

Figure 5: Monthly frequency distribution of the sexual maturity stages the Omani-Indian oil sardine (*Sardinella longiceps*) for samples collected from Al-Seeb area.

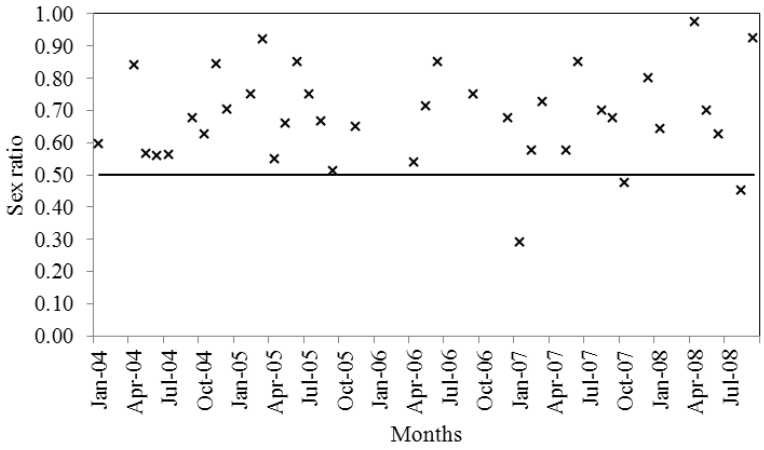

Figure 6: Sex ratio versus months for *Sardinella longiceps*.

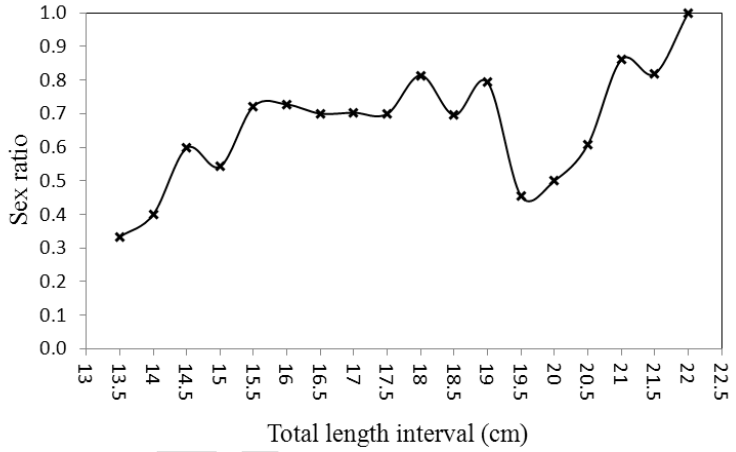

Figure 7: Sex ratio versus total length of lower class interval for *Sardinella longiceps*.

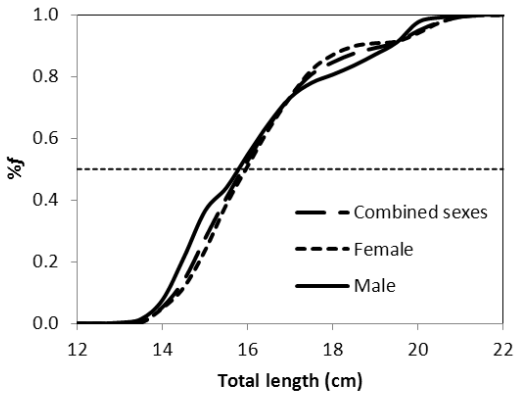

Figure 8: Relationship between the total length (TL in cm) and the cumulative frequency (%*f)* of the Omani-Indian oil sardine (*Sardinella longiceps*) samples collected from Al-Seeb area, Oman (January 2004–December 2008).

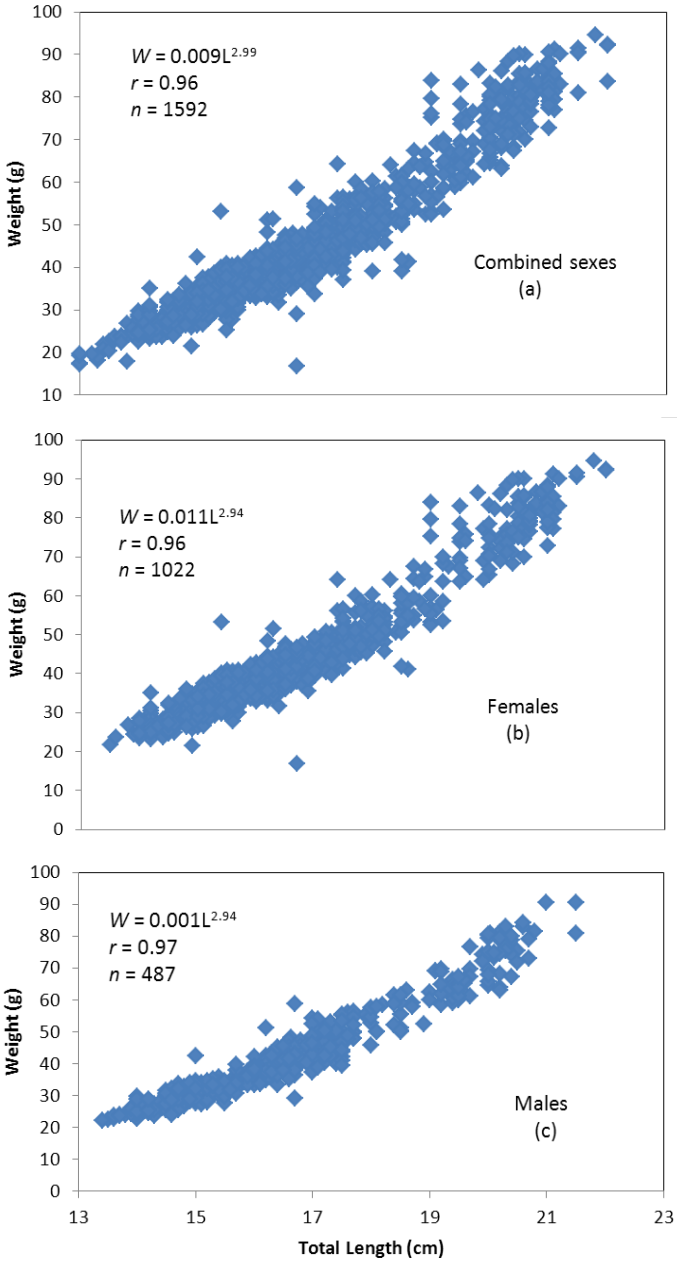

Figure 9: Length–weight relationship of the Omani-Indian oil sardine (*Sardinella longiceps*) collected from Al-Seeb area, Oman (January 2004–December 2008). (a) Combined sex, (b) female, and (c) male sardines.

3.4. Annual variation in the gonadosomatic index and the relative condition factor (K_n)

During the sampling period, the GSI for the combined sexes varied from one year to another. The GSI values were maximum in October, June, and July, September, June, and January and September for the years 2004, 2005, 2006, 2007, and 2008, respectively (Figure 10). The mean GSI during the sampling period was 3.88 ± 0.093 for the combined sex, 3.76 ± 0.072 for the female and 3.87 ± 0.16 for the male sardines. The maximum GSI values observed were within 13.5 to 16.0 cm and 21.5 to 21.9-cm range length intervals for the female and male, respectively (Figure 11).

During the sampling period, the relative condition factor K_n varied from one year to another and ranged from 0.36 to 1.46 with a mean of 0.9 ± 0.08. Condition factor for sardines during all these years was inversely related to the GSI values (Figure 10). The observed mean condition values for the years 2004, 2005, 2006, 2007, and 2008 were 0.9 ± 0.07, 0.91 ± 0.068, 0.9 ± 0.067, 0.89 ± 0.073, and 0.93 ± 0.92, respectively. These results indicated that fish sampled in 2008 had better condition factor than rest of the years. In general, the condition factor for females had wider fluctuation range (0.36–1.46) than for males (0.62–1.26). Both sexes showed no difference in the mean condition factor, that is 0.91 ± 0.07 for the males and 0.91 ± 0.08 for the females.

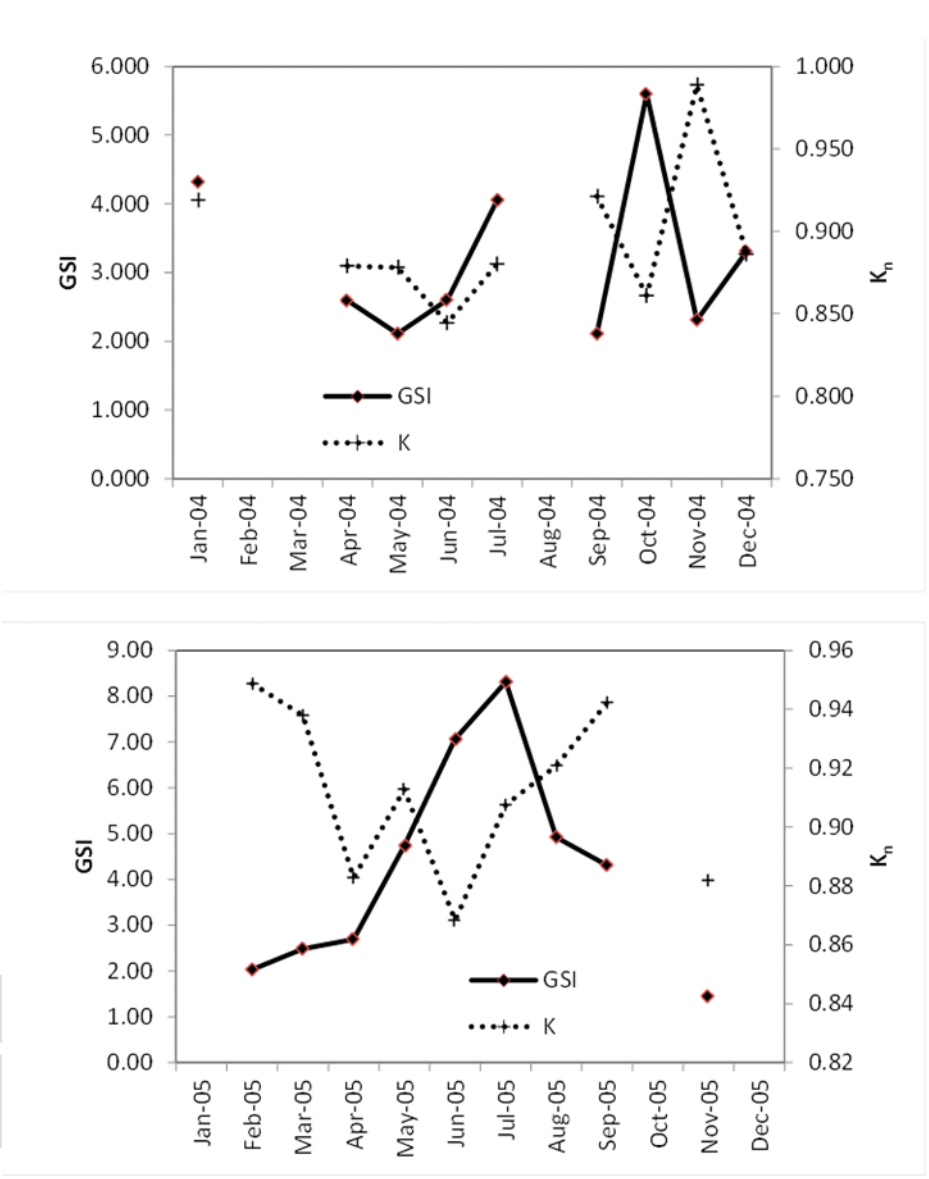

Figure 10: Monthly variations in the gonadosomatic index (GSI) and the condition factor (*K*) for the combined sexes of the Omani-Indian oil sardine (*S. longiceps*) samples collected from Al-Seeb area, Oman (January 2004–December 2008).

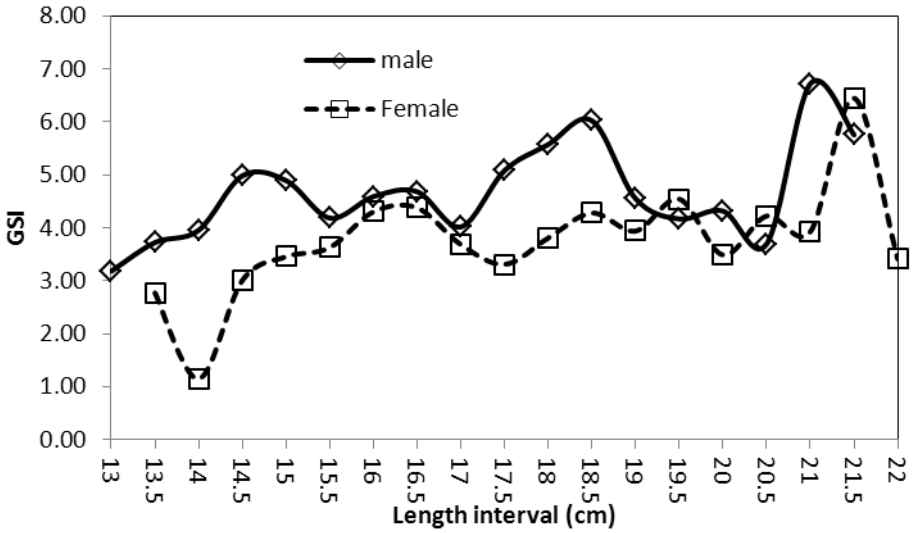

Figure 11: Relationship between gonadosomatic index (GSI) and total length (cm) for the male and female sardines.

4. Discussion

The lengths of sardines sampled during the 5-year sampling period ranged from 11.9 to 22.0 cm. The largest sardine sampled in this study was a female with a total length of 22.0 cm and was larger (TL = 21.9 cm, female) than the one sampled in 1997–1998 [1], while it was larger (TL = 19.6 cm, female) than the one sampled in 1991 [5]. These differences in the maximum lengths reported could be due to the different sampling techniques and the environmental conditions during the sampling period for each study.

The smallest mature female was 13.9 cm in length, while the smallest mature male was 13.4 cm. However, the observed length at 50% maturity was 16.35, 16.46, and 16.28 cm, for the combined sex, female, and male sardines, respectively. These values were found to be within the range of 15–17.4 cm as suggested by [10] for the Indian oil sardines. These values however were found to be less than that were observed by Siddeek *et al*. [5] for the same stock: 17.2, 16.9, and 17.2 cm for the combined sex, female, and male sardines, respectively. In general, the lengths reported here are higher than the length at first capture reported earlier (14.9 cm) for the Omani-Indian oil sardines [5]. This could be due to the continuous overfishing of small coastal sardines by the traditional fishing gear over the past years.

Having found male sardines with smaller size at length at 50% maturity and the dominance of mature females with larger size suggests that the female sardines mature late but after maturation their growth rates increase while the growth rates of the males decrease after maturation.

Spawning season of sardines varied from one year to another and it was identified to be in October, June, and July, September, June, and January and September for the years 2004, 2005, 2006, 2007, and 2008, respectively. The Omani sardines were also reported to spawn in March, August, and February [1] and April [5]. These wide spawning modes indicate that sardines release their eggs in batches and they are ready to spawn whenever the environmental conditions are favorable. The presence of all the maturity stages in the sampled sardines during the study period supported the multiple spawning behavior of the sardines (Figure 4b). This pattern was in agreement with observations of [1] and [11] for the same stock. In general, for a batch-fecund fish the reported GSIs depend on the sampling area, time, and occasionally on the type of gears used to catch the samples.

Relative condition factor K_n is an indication of the fish health and its well being. The current results indicated that the K_n values for sardines fluctuated within the sampling period and it was inversely related to the GSI or the spawning peaks. This indicates that the sardines feed well before the spawning period and use their stored energy for spawning.

The female sardines dominated and outnumbered the male sardines in different size classes and months during the sampling period. This was also observed in the local and regional studies for the same species [1, 5, 12]. The obtained sex ratio of 0.67 in the current study was higher than 0.60 that was obtained by Al-Jufaili in 2011 for the same stock. In contrast to the current results [11], observed a sex ratio of 1 : 1 (0.5) for the data collected between 1985 and 1986 from the same area. The monthly sex ratio fluctuated between 0.29 and 0.98 and the males outnumbered the females only in 3 months. The monthly sex ratios for the above-mentioned 3 months were: January 2007 (0.29), October 2007 (0.48), and August 2008 (0.45). The higher occurrence of females in the above-reported studies could be due to shoaling behavior of the sardines, vulnerability to the fishing gear, and differences in the female versus male growth rates. Sex ratio was reported to be the highest during the spawning period which ranged from 0.63 to 0.9. The males dominated the smaller length class of 13.5–14 cm in the entire sample, whereas the proportion of females increased with length.

Competing Interests
None declared.

Acknowledgement
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References
[1] Al-Jufaili SM, 2011. Weight–length relationships, gonadosomatic indeces, sex ratios and relative weight of the Omani-Indian Oil sardine, *Sardinella longiceps* (Valenciennes 1847) from Al-Seeb area; Sultanate of Oman. Advanced Journal of Food Science and Technology, 3: 245–249.
[2] Al-Jufaili SM, 2007. Conceptual model for sardine and anchovy inverse cyclic behavior in abundance. Journal of Food, Agriculture & Environment, 5: 317–327.
[3] Bal DV, Rao KV, 1984. Marine Fisheries of India. New Delhi, India: Tata McGraw-Hill Publishing Company.
[4] Dorr III JA, Al-Bulushi M, Al-Hijri M, 1990. Stock Assessment and Management of *Sardinella longiceps* in the Sultanate of Oman. Research Report. Marine Science and Fisheries Center, Ministry of Agriculture and Fisheries, Muscat, Sultanate of Oman.
[5] Siddeek MSM, Al-Habsi HN, Al-Jufaili SM, Al-Ghafry IN, 1994. Spawning Cycle, Recruitment Patterns, and Maturity Length of Indian Oil Sardine at Al-Azaiba, in the Gulf of Oman. In: Chou LM, *et al*. eds., The Third Asian Fisheries Forum, Singapore, 484–487.
[6] Nielsen LA, Johnson DL, 1995. Fisheries Techniques. Blacksburg, VA, USA: Southern Printing Company Inc.
[7] Ricker WE, 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin of Fisheries Research Board, Can. No. 191: 382 pp.
[8] LeCren ED, 1951. The length–weight relationship and seasonal cycle in gonad weight and condition in the perch *Perca fluviatilis*. Journal of Animal Ecology, 20: 201–219.
[9] King M, 2007. Fisheries Biology, Assessment and Management. UL: Wiley-Blackwell, 400pp.
[10] Nair RV, 1973. Indian Sardines (Their Biology and Fishery). Publication and Information Directorate, Council of Scientific and Industrial Research, New Delhi, India.
[11] Al-Barwani MA, Arundhati P, Dorr III J, *et al*., 1989. Studies on the Biology of *Sardinella longiceps* in the Sultanate of Oman, 1985–1986. Ministry of Agriculture and Fisheries, Kuwait Bulletin of Marine Science, 10: 201–209.
[12] Deshmukh AV, Kovale SR, Sawant MS, Shirdhankar MM, Funde AB, 2010. Reproductive biology of S*ardinella longiceps* along Ratnagiri coast off Maharashtra. Indian Journal of Marine Sciences, 39: 274–279.
[13] Dorr III JA, 1991. Small Pelagics Final Report for the Contract for Technical Services for Staffing. The Marine Science and Fisheries Center. Project No. 272-0101.1-1.
[14] Pauly D, 1984. Fish population dynamics in tropical water: a manual for use with programmable calculators. ICLARM Studies and Reviews, 8: 325.
[15] Valdés P, García-Alcázar A, Abdel I, Arizcun M, Suárez C, Abellán E, 2004. Seasonal changes on gonadosomatic index and maturation stages in common pandora *Pagellus erythrinus* (L.). Aquaculture International, 12: 333–343.