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Maturation and spawning of the Indian oil sardine *Sardinella longiceps* Val. from the Sohar coast, Sultanate of Oman

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Original Article

Abstract

Maturation and spawning of the Indian oil sardine *Sardinella longiceps* was studied between October 2007 and September 2009 from Sohar along the coast of Sea of Oman. The species spawned during February-March and September-October. The SST did not clearly indicate its influence in gonad development. While males matured (Lm) at 156 mm TL, females matured at 163 mm TL. Females were dominant in the commercial catches and the annual male to female ratio (1: 1.49) was significantly different. Fecundity varied from 22,456 to 61,867 eggs with the average of 40,479 eggs per female. The study indicates that no intervention is needed to regulate the Indian oil sardine fishery along the Sohar coast.

Keywords: *Sardinella longiceps, SST, GSI, Kn, length at maturity, spawning season, sex- ratio, fecundity, Sea of Oman.*

Introduction

The Indian oil sardine *Sardinella longiceps* (Family: Clupeidae) is a small pelagic fish that occurs in bulk in the commercial catches in most countries bordering the Indian Ocean and forms a cheap source of animal protein for millions of coastal people (Vivekanandan *et al*., 2008). Being a plankton feeder with population doubling time of less than 15 months, its role in the marine ecosystem as forage fish for larger predators is significant (Krishnakumar *et al*., 2008; Froese and Pauly, 2011).

Along the coasts of Oman (Arabian Gulf, Sea of Oman and Arabian Sea), the Indian oil sardine is the main target species for the artisanal fishers beach seines, boat seines, gillnets and cast nets for capture of this species (Al-Abdessalaam, 1995; GoSO, 2010). The catches of Indian oil sardine in the sultanate varied considerably from year to year which ranged from 26,000 t to 47,000 t for the period 2000-2009 (GoSO, 2003; 2009). The fish is marketed mostly fresh for human consumption or sundried to use as fertilizer or cattle feed. The oil sardine is used as live-bait for fishing larger pelagic fishes or as baits in the traps for demersal fishery.

Though, the species is commercially important in Oman, studies on the Indian oil sardine are few and fragmentary. The only detailed investigation available till date on the biological characteristics of the species from the Omani waters is more than two decades old (Al-Barwani *et al*, 1989). The studies of Siddeek *et al.* (1994), Al-Jufaili *et al.* (2006) and Al-Jufaili (2011) Al-Seeb are concerned with some aspects of reproduction of *S. longiceps* from the coasts of Muscat region. The present study is the first investigation on the reproductive biology of the Indian oil sardine from Sohar in Batinah region bordering the Sea of Oman.

Fig. 1. Map showing the sampling location

Material and methods

A total of 502 fish were collected from Sohar (Fig.1) landed by shore seines, gillnets and castnets on monthly basis between October 2007 and September 2009. However, during November and December of both the years, no sample could be collected. The pooled sample was considered for analysis.

The fish were brought to the laboratory in ice box and after washing each fish was measured to total length (TL) to the nearest 1 mm using fish measuring board and the total wet weight (TW) was recorded to the nearest 1 g using an electronic balance. Then, the fish were dissected out and, the sex and stage of maturity of the gonad were recognized based on the macroscopic appearance of the gonads and their extent of occupying in the body cavity. The gonads were removed and weighed to the nearest 0.01 g using an electronic balance and ovaries were preserved in 5% neutral formalin for ova diameter and fecundity estimations.

Maturity stages

Seven stages of maturity of fish (I-Immature 1; II-Immature 2; III-Maturing 1; IV-Maturing 2; V-Mature; VI-Ripe/Running and VII-Spent) were recognized both in females and males (Jayabalan *et al.*, MS) with slight modification of the key provided by Antony Raja (1969) who recognized the following stages, I-Immature; IIa-Virgin maturing; IIb-Spent resting; IV-Maturing; V-Mature; VI-Ripe; VIIa-Partially spent and VIIb-Spent. However, fish with running/ripe gonads (stage VI) could not be collected in the present study.

Development of ova to maturity

To understand the development of ova from immature to mature condition, 24 ovaries in different maturity stages excepting stage VI were considered. The diameters of about 200 ova from mid-region of each ovary preserved in 5% neutral formalin were measured using an ocular micrometer fitted to the eye piece of a microscope as followed by Clark (1934), Prabhu (1956) and Jayabalan (1986). Each ocular micrometer division was equal to 13 μm and the diameters of immature ova less than 78 μm were not measured from stage II onwards as they represented the general egg stock. The diameters of ova from each stage were pooled and grouped into 39 μm size classes for percentage frequency curves.

Estimation of length at first maturity

The mean size at first sexual maturity (Lm) was determined for males and females by fitting a logistic function to the proportion of mature fish against length interval. To determine size at first sexual maturity (Lm), males and females were grouped separately into 1 cm length groups and the gonads from stage III onwards were considered as mature. A logistic function was fitted to the proportion of mature fish against length class as given by King (1995) as,

$$P = 1/ (1 + \exp (-r (L-Lm)))$$

where, P = proportion of mature fish in each length class L, r = the slope of the maturity curve and Lm = length at 50% maturity

Spawning season

i. Occurrence of mature gonads: Spawning season of the species was determined by plotting the monthly percentage occurrence of different maturity stages of gonads in males and females.

ii. Gonado-somatic index: To determine the monthly gonado-somatic index (GSI) for males and females the formula,

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

was used where, GW represents the gonad weight (g); TW, the total body weight (g) and GSI, the index.

To relate the influence of monthly surface water temperature (SST °C) on GSI, the monthly temperature data for Sohar were obtained from the environmental data base of the Marine Ecology Division of the centre.

iii. Relative condition factor (Kn): The monthly relative condition factor (Kn) for males and females was estimated adapting the formula of Le Cren (1951) as,

$Kn = TW/aL^b$

where TW = observed weight (g), aL^b = calculated weight obtained from the length-weight relationship.

Fecundity

To estimate fecundity, 20 ovaries in stage were used. From pre-weighed ovary, a small portion was removed and weighed to the nearest 0.001g using an electronic microbalance. The piece of the ovary was then preserved in 'modified Gilson's fluid' (Bagenal and Braum, 1971) for few days for clear separation of eggs. Later, mature eggs in the piece of the ovary were counted using a binocular microscope. The total number of mature eggs in the whole ovary was determined from the number of mature eggs in the piece of the ovary as,

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

The relationships between fecundity and total length of the fish as well as the body weight and ovary weight were calculated as,

$F = aX^b$

where, F=fecundity, a = constant, X = variable (fish length, fish weight or ovary weight) and b = the exponent. The exponential relationship was transformed in to a straight line logarithmic form based on the equation,

Log F = log a+ b log X

Sex-ratio

The male: female ratio of fish in the commercial catches was estimated. Independent X2 goodness of fit tests was conducted to determine whether sex ratios differed significantly from unity for the whole sample and individual months.

Results and discussion

Development of intra-ovarian eggs to maturity and spawning

In stage I ovary, about 66% of ova were immature and their diameters measured up to 39 μm; while, few larger ova measured up to 117 μm (Fig. 2). From the immature group of eggs, a batch of ova was separated for subsequent development that formed modes at 130-156 μm in stage

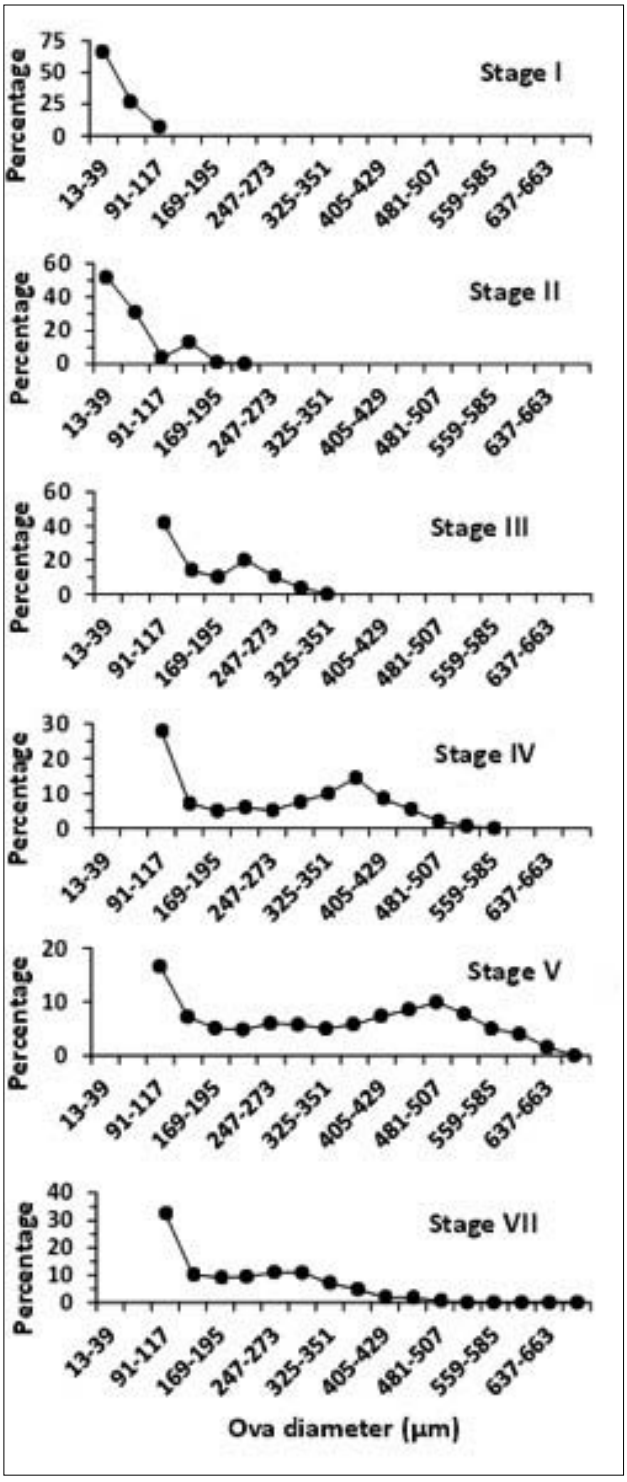

Fig. 2. Development of ova to maturity in *S. longiceps* in Omani waters

II, at 208-234 μm in stage III, at 364-390 μm in stage IV and at 481-507 μm in stage V ovaries. There were no other prominent modes in any of the stages excepting in spent ovary where a small mode at 286-312 μm was present besides disintegrating ripe ova.

The overall developmental process of eggs in different stages of ovaries was almost identical of the findings in fish from the Mahout coast in Oman (Jayabalan *et al*., MS). In the present study, as the mature ova in stage V ovary were almost 49% of the total eggs measured and had a wide size range of 325-351 μm to 715-741 μm, individual fish appeared to spawn for longer duration during the spawning season (Prabhu, 1956) in Sohar coast.

The atretic eggs in spent ovaries of *S. longiceps* were the unspawned eggs that might undergo resorption (Antony Raja, 1967; 1971). However, for the Indian oil sardine along the coasts of India, Nair (1953) suggested a single spawning in the entire life of fish whereas Antony Raja (1967) reported the second spawning in a fish.

Spawning season

Gonado-somatic Index

The monthly gonado-somatic indices pooled for 2007-08 and

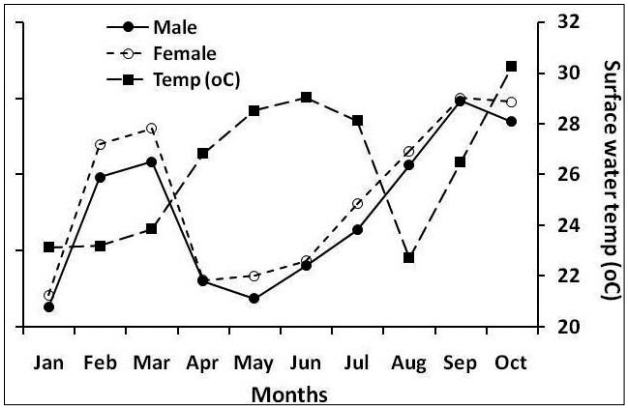

Fig. 3. Monthly SST and GSI of *S. longiceps i*n Sohar during 2007-2009

2008-09 (Fig. 3) showed that the females always recorded higher values than the males. In both the sexes, the monthly GSI increased from January to March and declined during April and May. Thereafter, the GSI progressively increased and reached the peak values both in males (5.94) and females (6.0) during September. The GSI values were higher during February, March, August-October than the weighted average in males (2.92) and in females (3.37).

While, the lower monthly SST in Sohar during August (22.7 °C), February (23.2°C) and March (23.9°C) coincided with higher GSI in both the sexes, higher temperatures during September and October matched with higher GSI (Fig. 3). This indicates that temperature is not the prime factor that influences gonad development in Indian oil sardine.

Relative condition factor (Kn)

The monthly Kn values pooled for 2007-08 and 2008-09 showed that the females always had higher values than males except during June (Fig. 4). The highest value in male was recorded during February (1.2029) and in females during March (1.2408). In both the sexes, the Kn values started declining after the peak values. While, the Kn values were higher in males during January-March than the weighted average (1.05435), in females the values were higher during

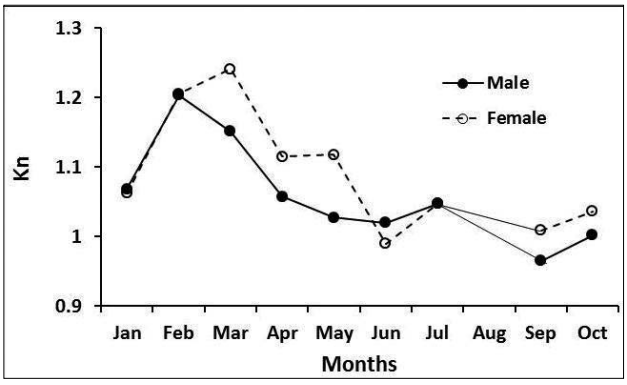

Fig. 4. Monthly Kn in *S. longiceps* at Sohar during 2007-2009

February-May than the weighted average value (1.08539). Similar to GSI, the higher Kn values were recorded during February and March.

Monthly occurrence of different stages of gonads

The percentage occurrence of various maturity stages of gonads during different months (Fig. 5) shows that higher percentages of immature males and females occurred during January, April-July. The mature (stage V) fish occurred during January-March and spent (stage VII) fish in both the sexes were recorded during February and March. Again mature gonads occurred during August-October with spent fish during September and October. This indicates that the spawning of Indian oil sardine in the Sohar region occurred during two seasons, the first one during February-March and the second season being September-October. The higher GSI during the above months also supported two spawning seasons. Al-Jufaily (2011) reported the spawning of *S. longiceps* during February-March and August along Al-Seeb coast. Though, both the observations were from the coasts of Sea of Oman,

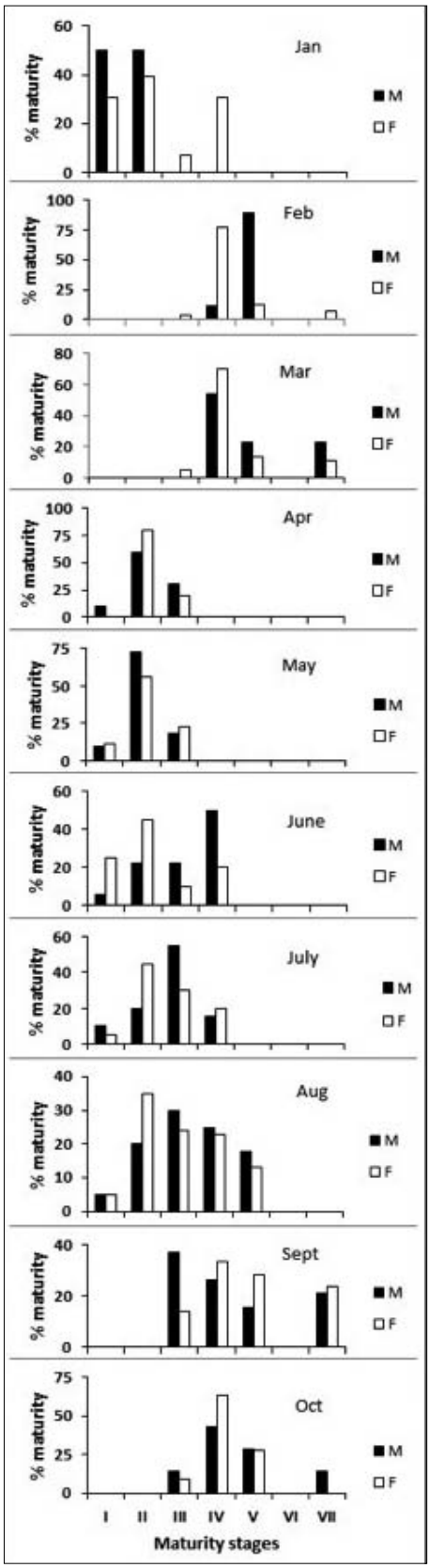

Fig. 5. Distribution of monthly maturity stages of gonads of *S. longiceps* in Sohar

there is agreement on the first spawning season and the shift in the second spawning period might be due to geographical variation.

The spawning season of *S. longiceps* along the Indian coasts is closely associated with the onset of monsoon and other environmental parameters (Nair, 1959; Antony Raja, 1972). Similar to Indian waters, the environmental conditions of the sea might induce the peak period of spawning in fish which would vary from year to year and from region to region in Oman (Siddeek *et al.*, 1994; Al-Jufaily *et al.*, 2006). As the development of gonads in fishes is primarily related to the energy attained from food (Lambert and Dutil, 1998; Darriba *et al.*, 2005), the dietary status would also influence reproductive success in wild fish populations (Lambert *et al.*, 2000).

Length at first maturity

The percentage occurrence of mature individuals of males and females in different size classes (Fig. 6) showed that the fish measuring less than 135 mm TL were all immature. In the size class 136-140 mm, while 16.7% of females attain maturity, in males 25% of individuals were in mature condition. The percentage of mature males and females increased with the increase of length. While the 50% of maturity (Lm50) was

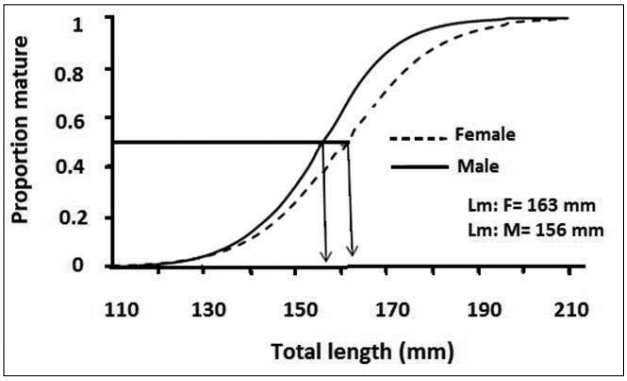

Fig. 6. Length at first maturity of *S. longiceps* in Sohar

attained at 156 mm in males and 163 mm in females, all males above 175 mm and females above 180 mm were in mature condition. The first spent male and female fish were recorded in 136-140 mm size group.

While, the Indian oil sardine would attain maturity at a length between 15 cm and 17 cm along the Indian coasts (Hornell and Nayudu, 1924; Devanesan, 1943; Chidambaram and Venkataraman, 1946; Antony Raja, 1967; Dhulkhed, 1967), along the coasts of Al-Azaiba and Seeb in Oman, the fish attained maturity between 15.9cm and 16.9 cm (Siddeek *et al.*, 1994; Al-Jufaily, 2011). The estimates of Lm for males and

Table-1. Monthly sex-ratio of *S. longiceps* in Sohar (pooled 2007-08 & 2008-09)

Months	Male	Female	M: F	X 2 value	P-value
January	12	33	1: 2.75	9.8*	0.001745
February	18	41	1: 2.28	8.966*	0.00275
March	19	47	1: 2.47	11.8787*	0.000568
April	22	20	1: 0.91	0.095	0.7576
May	23	19	1: 0.83	0.38095	0.53709
June	18	32	1: 1.78	3.92*	0.0477
July	23	25	1: 1.09	0.0833	0.772
August	26	26	1:1	0	-
September	25	21	1: 0.84	0.3478	0.5553
October	19	33	1: 1.74	3.7892	0.0522
Total	205	297	1: 1.49	18.8606*	1.44E-05

*Significant

females in Sohar in the present study are almost close to the earlier observations in India and Oman.

Sex-ratio

The monthly sex-ratio of males to females indicated the dominance of females over males during most part of the year and the annual sex-ratio stood at 1 male: 1.49 female (Table-1). The chi-square test indicated the monthly sex-ratios were significantly different during January to March and June, and the annual sex-ratio differed significantly from the expected ratio of 1:1.

In the commercial catches, females were higher in number than males in Sohar (Zaki *et al*., 2011) as observed from Al-Seeb in Oman (Al-Jufaily, 2011) and from Indian coasts (Annigeri *et al*., 1992; Deshmukh *et al*., 2010). However, the sex-ratio was found to be close to 1:1 in an earlier study from Oman (Al-Barwani *et al*., 1989). The dominance of females during February and March which were the spawning months observed in the present study indicates that more number of females would involve in spawning activity and this will help in recruitment. The dominance of individuals of one sex in the landings may also be due to segregation of sexes and one sex may be more vulnerable to capture (James, 1967; Kalita and Jayabalan, 1990).

Fecundity

The fecundity of *S. longiceps* in Sohar generally increased with increase in length, weight and ovary weight of fish (Fig. 7A, 7B & 7C). While, the minimum fecundity (22,456 eggs) was estimated from a female measuring 159 mm TL, 36 g of body weight and 1.05g of ovary weight, the highest fecundity

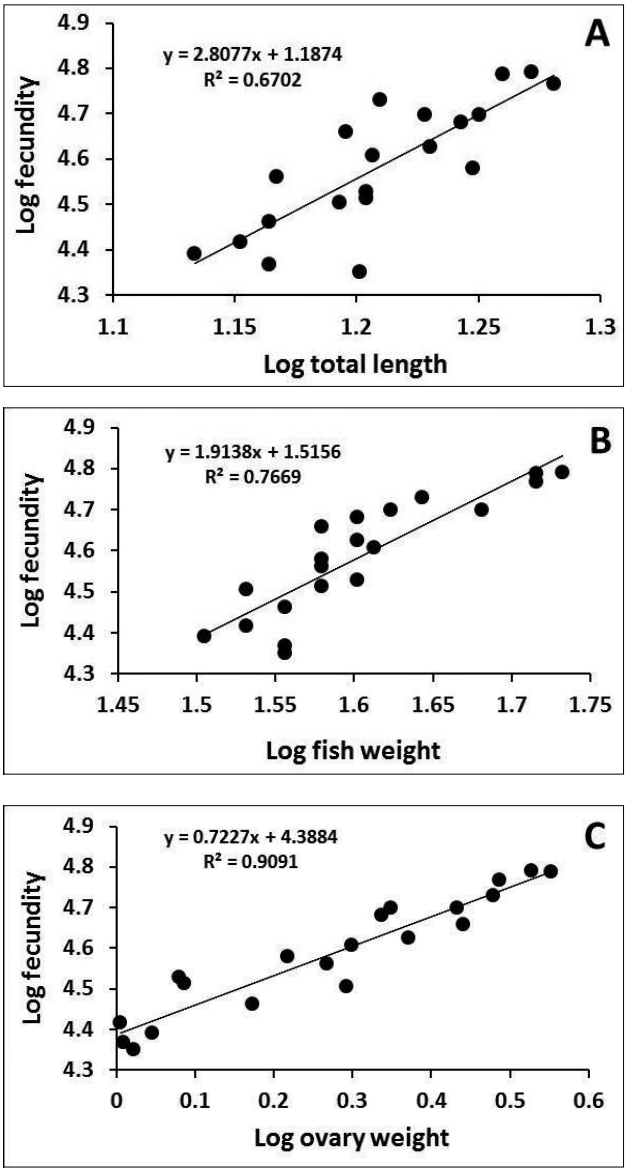

Fig. 7. Relationship between fecundity and (A) total length, (B) total weight and (C) ovary weight of *S. longiceps* in Sohar

(61,867 eggs) were recorded in an individual measuring 187 mm TL, 54 g of body weight and 3.37 g of ovary weight.

The relationship between the fecundity (F) and total length of fish (TL) (Fig. 7 A) can be expressed by the equation,

$\text{Log } F = 1.1874 + 2.8077 \log L$ ($R^2 = 0.6702$)

The relationship between the fecundity (F) and total weight of fish (Tw) (Fig. 7B) was calculated as,

$\text{Log } F = 1.5156 + 1.9138 \log Tw$ ($R^2 = 0.7669$)

The relationship between the fecundity (F) and ovary weight (Ow) (Fig. 7C) was found to be,

$\text{Log } F = 4.3884 + 0.7227 \log Ow \ (R^2 = 0.9091)$

The relationship between the fecundity (F) and ovary weight (Ow) (Fig. 7C) was found to be,

$F = 14486*Ow + 10999 \ (R^2 = 0.9091)$

Variations in fecundity estimates of Indian oil sardine have been reported from Indian coasts that ranged from 27,000 eggs to 80,000 eggs (Devanesan and Chidambaram, 1948; Nair and Chidambaram, 1951; Nair, 1960; Balan, 1965, 1984; Antony Raja, 1971; Jaiswal, 1969; Deshmukh *et al.*, 2010). The average fecundity of 40,479 eggs in *S. longiceps* in Sohar region in the present study was higher than in Muscat coast (19,000 eggs) (Al-Jufaily *et al.*, 2006) and lower than in Mahout coast (71,835 eggs) in Oman (Jayabalan *et al.*, MS).

The average length at capture of *S. longiceps* estimated in the parallel study in Sohar stood at 168 mm (Zaki *et al.*, 2011) and hence, there is no need for mesh size regulation of the nets along Sohar coast. It is also evident from the growth studies that majority of fish was virgin spawners along the Sohar coast (Zaki *et al.*, 2011)

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