Indian Journal of Geo Marine Sciences
Vol. 50 (12), December 2021, pp. 1037-1042

Analysis of reproductive patterns of *Sardinella longiceps* (Valenciennes, 1847) from the Mumbai Sea, Maharashtra, India

S K Ahirwal*[,a], A K Jaiswar[b], S K Chakraborty[b], K Sarma[a], T Kumar[a], J Singh[a] & R Bavithra[a]

[a]ICAR-Research Complex for Eastern Region, Patna – 800 014, Bihar, India

[b]ICAR- Central Institute of Fisheries Education, Versova, Mumbai – 400 061, India

*[E-mail: surendraahirwal@gmail.com]

Received 22 June 2019; revised 03 December 2021

In developing countries, management of fisheries resources is directly or indirectly dependent on fish reproductive biology & conservation of the breeding grounds. Indian Oil Sardine fishery is a commercially important pelagic fishery along the coast of Mumbai. A Ganado-somatic index value of females was maximum (8.20) in September and minimum (0.38) in January. For males, the maximum Gonado-somatic index was 8.36 in September and the minimum 0.29 in February. Based on sex ratios month-wise, females were slightly more dominant in all months. There is a significant difference in the length-wise distribution of sexes, with a large number of females in higher length groups. Females attain the length at first maturity at 166.5 mm, and matured ovaries were seen in September and October, with a maximum percentage in September. It is estimated that the absolute fecundity ranged between 28,860 and 52,646, and the relative fecundity ranged between 450 and 684 number eggs per gram of fish weight.

[**Keywords**: Fecundity, Gonado-somatic index, Maturity, *Sardinella longiceps*, Sex ratio]

Introduction

Clupeidae, a taxonomically diverse family of fishes distributed throughout the world, make up one-third of all marine fish caught in India[1]. Around 106 species of clupeid fishes have been found in Indian waters, including the 14 species of lesser sardines, and one species of Indian oil sardine. Geographically, the species occurs along the coasts of India, Africa, Oman, Indonesia, the Philippines, and Vietnam[2]. It is essential to have a solid understanding of fish reproduction biology to assess fish populations rationally and provide science-based recommendations for fisheries management[3,4]. A lack of knowledge regarding the biology of fish can produce overfishing and ineffective management of the Indian oil sardine fishery[5,6]. The compatibility of the spawning season with the optimal conditions for larval survival determines the success of reproductive activities[7,8]. Stock assessment models combine spawning periodicity and size at first maturity, laying the groundwork for management measures such as minimum legal size for retention and temporal and geographic fishing limitations[9,10]. The productivity of fish resources is largely influenced by the reproductive traits of the particular species[11]. Given the importance of reproductive biology, the investigation has been done on the Indian oil sardine along the west coast of India[12-19]. However, no reports on the reproductive traits of this species were found from the Mumbai Sea, where it forms an important fishery. Hence, the study was conducted to access the biological parameters of this species from the Mumbai Sea. Present findings will be useful for the conservation and sustainable utilization of the resources along the coast of Mumbai waters.

Materials and Methods

In the present study, specimens were collected weekly from Versova, Sassoon Docks, and New Ferry Wharf fish landing centers along the Mumbai coast from September 2013 to May 2014 (Fig. 1). The weight of each specimen and gonad weight were taken to the nearest 0.05 gm by electronic balance for GSI calculation, and the GSI ratio was determined using the equation below[20]:

$$\text{GSI} = \frac{\text{Weight of gonad}}{\text{Total body weight}} \text{X } 100$$

The gravimetric method was used to determine the species' fecundity. It is based on the relationship between the weight of the ovary and the density of the

oocyte in the ovary. To estimate fecundity, a total of 7 ripe preserved ovaries were used. A subsample of 0.05 g was weighed from each ovary's front, middle, and posterior parts with a precision of 0.001 g. After separating the eggs using Gilson's fluid, subsamples were placed uniformly on a counting slide with a few drops of water. The number of mature ova was counted, and the average number of three sections was used to calculate fecundity using the formula below.

$$\text{Absolute fecundity} = \frac{\text{No. of ova in the subsample}}{\text{Weight of subsample}} \text{ X Total ovary weight}$$

The relative fecundity represents the number of eggs per unit body weight. The relation of fecundity *F* with total length (TL), total weight (TW) and ovary weight (OW) was established by formula[21]:

Fecundity = $_aTL^b$, Fecundity = $_aTW^b$, and Fecundity = $_aOW^b$

Where, TL denotes total length in millimeters, TW denotes total body weight in grams, and OW denotes ovarian weight in grams (g). The correlation coefficient between fecundity, total length, and body weight was calculated using the least square method. Sex ratio of the samples was determined using Chi-square test[22]:

$$\chi^2 = \frac{(O-E)2}{E}$$

Where, "O" stands for observed frequencies, whereas "E" stands for expected frequencies.

For the study of length at first maturity, cumulative percentage was drawn against length and the length at which half (50 %) of the population became matured was considered as the length at first maturity[23].

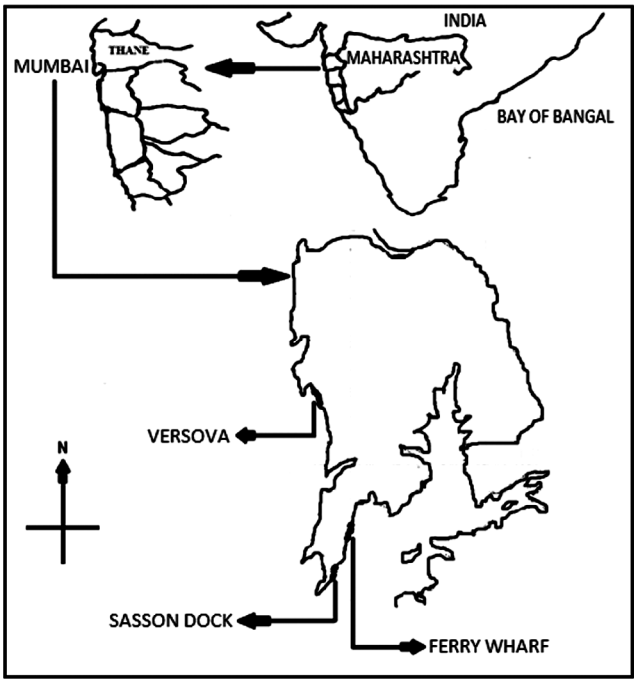

Fig. 1 — Map showing the sampling places at Mumbai coast

Results

In this study, observed high Gonado-somatic index for both the sexes in September and October suggests the possible spawning period of Indian oil sardine, which coincided with the monsoon condition/season. After that, there is no mature fish from November to May, which means fish spawn once a year (Table 1). For sex ratio analysis, random specimens were taken for each month, and the observed ratio was performed against the Chi-square (X^2) test for *n-2* degrees of freedom at a 5 % level of significance. Any significant variation was not found in the distribution of sexes in different months. However, fluctuation in sex ratio occurred from September to January with female dominance; after that, the male was more dominant than the females. Moreover, the overall sex ratio for the entire study period was 1:1.09, indicating a marginal dominance of females over males (Table 2). A total of 212 females of *S. longiceps* were examined for the estimation of minimum length at first maturity. Ovaries in III stage and onwards were considered mature in the present study. The

Table 1 — Month-wise sex ratio of *Sardinella longiceps*

Months	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Sex-ratio	1:1.21	1:1.62	1:0.78	1:1.24	1:1.16	1:0.56	1:0.68	1:0.87	1:0.91
X^2 value	0.15	1.54	0.61	0.54	0.12	0.98	0.17	0.14	0.13

Table 2 — Month-wise Gonado-somatic index of *Sardinella longiceps*

Months	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Male	8.3613	1.9822	0.3502	0.5891	0.4143	0.2879	0.3462	0.3162	0.4211
Female	8.2033	1.7362	0.5346	0.5907	0.3816	0.4019	0.4122	0.4353	0.5212

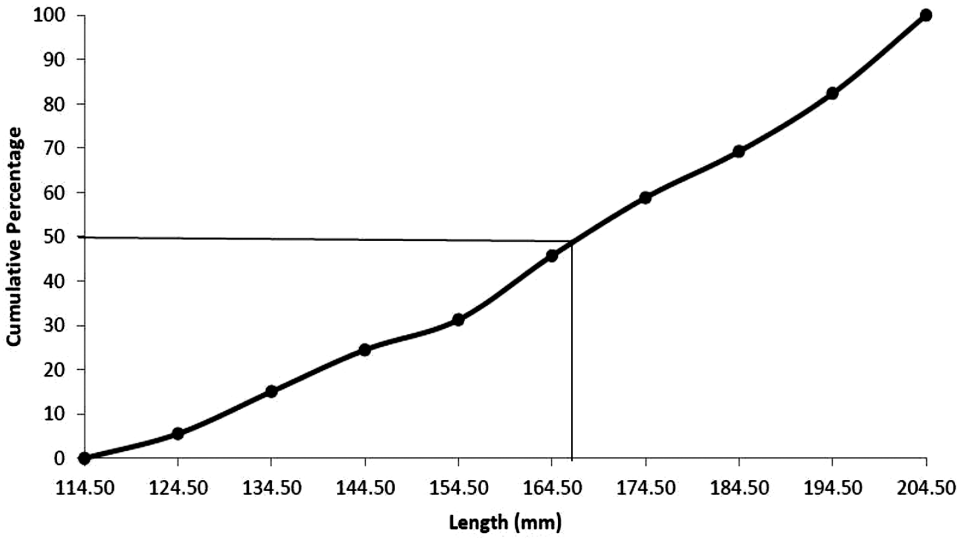

Fig. 2 — Length at first maturity of *Sardinella longiceps* (Females)

cumulative percentage of mature females was plotted against their length groups at 10 mm class intervals to create a maturity curve. It is found that the minimum size at which fish attains the first maturity was 166.5 mm (Fig. 2). Maturity stages I, II, and III appeared throughout the year, with the highest percentage distribution in January (61.90 percent), December (49.02 percent), and February (44.45 percent), respectively. However, stage IV and V has highest distribution in the month of April (23.08, 19.023 %), whereas mature specimens in stage VI (ripe) were observed in September (Fig. 3). Length-wise analysis revealed that maximum percentage distribution of maturity stages from I to III occurred in 100 – 109, 150 – 159 and 160 – 169 mm length groups, respectively. However, stage IV, V and VI has highest distribution in 170 – 179, 140 – 149 and 160 – 169 mm length groups, respectively. Moreover, stage VII has maximum dominancy in 200 – 209 mm and was least in 180 – 189 mm length group (Fig. 4). Fecundity was calculated for mature individuals whose lengths ranged from 167 to 207 mm and their weights ranged from 63.6 to 82.34 g. Fecundity ranged between 28,860 and 52,646 for an ovary weight of 5.26g and 7.92 g. The relative fecundity varied from 454 to 672 eggs per gram of body weight of fish. The linear relationship between fecundity of fish (F) with their total length (TL), body weight (TW), and ovary weight (OW) was established as given below:

Log F = 8.0214 + 5.5626 Log TL (R, 0.8307)
Log F = 0.7369 + 2.8280 Log TW (R, 0.8375)
Log F = 3.3893 + 1.5277 LogOW (R, 0.8772)

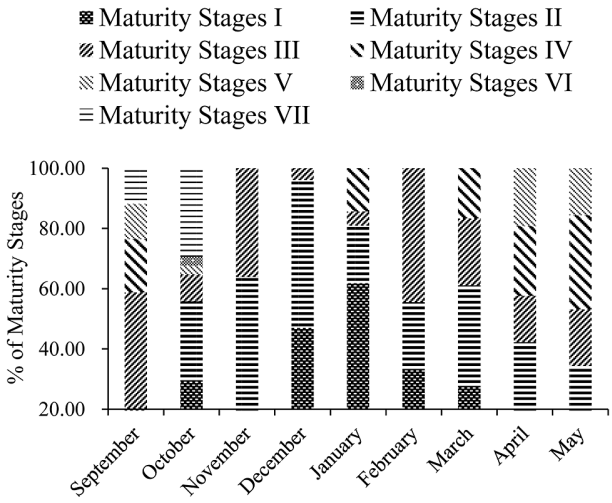

Fig. 3 — Month-wise percentage distribution of maturity stages in *Sardinella longiceps* (Female)

Based on the aforementioned linear relationship, a better relationship between fecundity and the ovary weight of fish was found.

Discussion

In the present investigation, it has been found that the species attains the first maturity at 166.5 mm total length. From the Malabar Coast and Gulf of Mannar, Hornell & Nayudu[24], Devanesan[25], and Abdussamad *et al.*[26] recorded the length of the first maturity as 150 mm, whereas Dhulkhed[27] and Al-Jufaili[28] reported it as 164 – 165 mm and 164.6 – 169 mm, respectively from the Karwar and Al-Seeb area in Oman. The variations between present findings and prior investigations, except for Dhulkhed[27] and

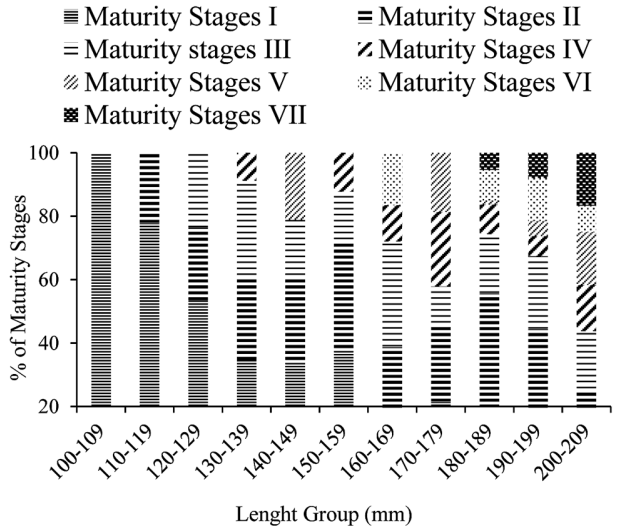

Fig. 4 — Length-wise percentage distribution of maturity stages in *Sardinella longiceps* (Female)

Al-Jufaili[28], could be attributed to variances in sampling methodology, deployment of different gears, and environmental conditions. Analysis of the month-wise sex ratio indicates slight dominance of females in all the months. The overall sex ratio also revealed a marginal dominance of females over males. A similar observation was reported on the same species from Ratnagiri waters, where females marginally dominated male population[29]. Based on length-wise sex ratio analysis, significant dominance of males occurred in the smaller length groups (110 – 169 mm), whereas female dominance occurred in the 170 mm and above length groups. The equal distribution of sexes in lower length (130 – 160 mm) and preponderance of females in 170 mm and above groups have been recorded from Calicut water[30]. The findings are consistent with previous findings on the same species from Muscat waters, where males dominated the smaller groups (135 – 140 mm) and females in the larger groups[32]. In present study the absolute fecundity ranged from 28,862 to 52,646, whereas relative fecundity from 454 to 672 eggs per gram. The results has close agreements with the previous finding on the same species from the Calicut and Muscat, Oman were researchers reported the fecundity of 30,000 to 38, 000 and 55,000 to 60,000, respectively[31,32]. On the other hand, from Gulf of Mannar[26] the observed fecundity was 58,000 whereas from Ratnagiri waters[29] ranged between 45,000 to 75,000 in the same species. The variation in the fecundity with the previous finding may be because only females at stage VI of maturity were used in present study. However, fish condition, body weight, age, size, and season of collection all influence the fecundity[33–37]. Seven maturity stages were found in Indian oil sardines, with the mature ovaries (VI) being acquired from September to October, with the highest percentage in September. However, the spawning season for Indian oil sardines along the Mumbai waters found to be from September to October. However, earlier authors described the spawning season of the species as May to August[24], July to September[29], June to August[38], June to October[39], June to September[40], and June to December[41]. Moreover, spawning seasonality is controlled by water temperature, rainfall, food availability and climate change[42–45].

Conclusion

Indian oil sardines are a major pelagic resource of the country, and many fishermen rely on this fishery for their livelihood. The present study revealed that both sexes had a higher Gonado-somatic index in September and October. Overall, sex ratio analysis showed a marginal dominance of females over the male population. Fecundity studies showed a better association with the ovary weight than total length and fish's total weight. This study provides baseline information on the species reproductive biology from the Mumbai waters. These are important parameters from a stock assessment point of view and are also useful to determine the sustainable yields and prepare fishery management plans for the future.

Acknowledgments

The authors are grateful to the Director, Central Institute of Fisheries Education (CIFE) Mumbai, for providing necessary facilities to successfully carry out the study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Author Contributions

All authors of this manuscript contributed to this research investigation. Conceptualization, field sample collection, and analysis were performed by SKA, AKJ, and SKC. The manuscript editing and reviewing have been done by KS, TK, JS, and BR.

References

1 Whitehead P J P, A review of the elopoid and clupeoid fishes of the Red Sea region, *Bull Brit Mus Nat Hist*, 12 (7) (1985) 227–281.

2 Rosa H J & Laevastu T, Comparison of biological and ecological characteristics of sardines and related species – a preliminary study, *Proceedings of world scientific meeting on the biology of sardines and related species, Rome*, 1960, pp. 523–552.

3 Cochrane K L, A fishery manager's guidebook: management measures and their application, In: *FAO fisheries technical paper*, No. 424, (Rome), 2002, pp. 231.

4 Hossain M Y, Hossen M A, Islam M S, Jasmine S, Nawer F, *et al.*, Reproductive biology of *Pethiaticto* (Cyprinidae) from the Gorai River (SW Bangladesh), *J Appl Ichthyol*, 33 (1) (2017) 1007–1014. doi: 10.1111/jai.13427

5 Kinas P G, Bayesian fishery stock assessment and decision making using adaptive importance sampling, *Can J Fish Aquat Sci*, 53 (1996) 414–423. doi: 10.1139/cjfas-53-2-414

6 Alves D C & Minte-Vera C V, Scientometric analysis of freshwater fisheries in Brazil: repeating past errors, *Rev Fish Bio*, 23 (2012) 113–126. doi: 10.1007/s11160-012-9282-6

7 Cushing D H, Dependence of recruitment on parent stock, *J Fish Res Can*, 30 (1973) 1965–1976. doi: 10.1139/f73-320

8 Lowerre-Barbieri S K, Ganias K, Saborido-Rey F, Murua H & Hunter J R, Reproductive timing in marine fishes: variability, temporal scales, and methods, *Mar Coast Fish*, 3 (2011) 71–97. doi: 10.1080/19425120.2011.556932

9 Hill B J, Keynote address: minimum legal sizes and their use in the management of Australian fisheries, In: *Minimum legal sizes and their use in fisheries management*, *Aust S Fish Biol Proc*, 9 (1990) p. 50.

10 Hall N G, Data requirements of multispecies, spatial, and ecosystem models, In: *Population Dynamics for Fisheries Management*, *Aust S Fish Biol Proc*, (1993) 108–113.

11 King M, *Fisheries biology, assessment and management*, (Blackwell Science, London, England), 1995, pp. 341.

12 George K C, A method for distinguishing the sex of the oil sardine, *Sardinella longiceps* Val, in the field, *Indian J Fish*, 6 (2) (1959) 322–326.

13 Antony Raja B T, Some aspects of spawning biology of oil sardine, *Sardinella longiceps* Val, *Indian J Fish*, 11 (1964) 45–120.

14 Antony Raja B T, Length-weight relationship in the oil sardine, *Sardinella longiceps* Val, *Indian J Fish*, 14 (1) (1967) 159–170.

15 Dhulkhed M H, Sea ratio and maturity stages of oil sardine, *Sardinella longiceps Val.* from the Mangalore Zone, *Indian J Fish*, 15 (1–2) (1967) 116–126.

16 Balan V, Fishery and biology of oil sardine *Sardinella longiceps* Val. off the Cochin coast, *Indian J Fish*, 18 (1–2) (1972) 135–147.

17 Gopinathan C K, Early stages of upwelling and decline in oil sardine fishery of Kerala, *J Mar Biol Assoc India*, 16 (3) (1974) 700–707.

18 Annigeri G G, Kurup K N, Kumaran M, Mohan M, Luther G, *et al*., Stock assessment of oil sardine, *Sardinella longiceps* Val., off West coast of India, *Indian J Fish*, 39 (3–4) (1992) 125–135.

19 Rohit P, Record size oil sardine (*Sardinella longiceps*) caught off Malpe, India, *J Mar Biol Assoc India*, 45 (2) (2003) 255–256.

20 Vladykov V D, Fecundity of wild speckled trout (*Salvelinus fontinalis*) in Quebec Lakes, *J Fish Res Bd Can*, 13 (1956) 799–841.

21 Bagenal T B, Aspects of fish fecundity, In: *Ecology of freshwater fish production*, (Blackwell Scientific Pub, Oxford), 1978, pp. 75–101.

22 Snedecor G W & Cochran W G, *Statistical Methods Oxford*, (IBH Publishing Co, New Delhi), 1967, pp. 593.

23 Wood H, Scottish herring shoals pre-spawning and spawning movements, *Fish Board Scot Sci Invest*, 1 (1930) 1–71.

24 Hornell J & Nayudu R M, A contribution to the life-history of the Indian sardine with the notes on the plankton of the Malabar Coast, *Madras Fish Bull*, 17 (5) (1924) 129–197.

25 Devanesan D W, A brief investigation into the causes of the fluctuations of the annual fishery of oil sardine of Malabar, *Sardinella longiceps* Cuv. & Val., determination of its age and an account of the discovery of its eggs and spawning ground, *Madras Fish Bull*, 28 (7) (1943) 1–24.

26 Abdussamad E M, Pillai N K, Moohammed O M M J & Jayabalan K, Sardines of the Gulf of Mannar ecosystem-fishery and resource characteristics of major species, *Indian J Fish*, 57 (4) (2010) 7–11.

27 Dhulkhed M H, Observations on the spawning behaviour of the Indian Oil sardine, *Sardinella longiceps* Valenenciennes, determined by ova diameter studies, *Indian J Fish*, 11A (1) (1964) 371–376.

28 Al-Jufaili S M, Weight-length relationships, gonad somatic indices, sex ratios and relative weight of the Omani-Indian oil sardine, *Sardinella longiceps* (Valenciennes, 1847) from Al-Seeb Area., Sultanate of Oman, *J Food Sci Tech*, 3 (4) (2012) 238–244.

29 Deshmukh A V, Kovale S R, Sawant M S, Shridhankar M M & Funde A B, Reproductive biology of *Sardinella longiceps* along Ratnagiri coast off Maharashtra, *Indian J Geo-Mar Sci*, 39 (2) (2010) 274–279.

30 Antony Raja B T, the Indian oil sardine, *Bull Cent Mar Fish Res Inst*, 16 (1969) p. 128.

31 Antony Raja B T, Fecundity fluctuations in the oil sardine, *Sardinella longiceps*, *Indian J Fish*, 18 (1–2) (1971) 84–98.

32 Al-Jufaili S M, Al-Azri A R, Al-Shuaily S S & Ambu-Ali A A, Observations on the fecundity and Gonado-somatic Index (GSI) of the Omani-Indian oil sardine *Sardinella longiceps* (Valenciennes, 1847), *Pak J Biol Sci*, 9 (4) (2006) 700–702.

33 Hunter J R, Lo N C H & Leong R J H, Batch fecundity in multiples pawning fishes, In: *An egg production method for estimating spawning biomass of pelagic fish: application to the northern anchovy, Engraulis mordax,* (National Oceanic and Atmospheric Administration, National Marine Fisheries Service, California, USA), 1985, pp. 66–77.

34 Rijnsdorp A D, Changes in fecundity of female North Sea Plaice (*Pleuronectes platessa*) between three periods since, *ICES J Mar Sci*, 48 (1991) 253–280. doi: 10.1093/icesjms/48.3.253

35 Ahirwal S K, Sarma K, Jaiswar A K, Chakraborty S K, Kumar T, *et al*., Age, growth and mortality parameters of Indian oil sardine *Sardinella longiceps* (Valenciennes, 1847) from Mumbai waters, off Maharashtra, India, *Indian J Fish*, 69 (1) (2022) 22-26. doi: 10.21077/ijf.2022.69.1.111934-02

36 Ahirwal S K, Jaiswar A K & Chakraborty S K, Biometric analysis of oil sardine, *Sardinella longiceps* (Valenciennes, 1847) from Mumbai coasts of Maharashtra, India, *Indian J Geo-Mar Sci*, 46 (09) (2017) 1810-1817.

37 Witthames P R, Walker G M, Dinis M T & Whiting C L, The geographical variation in the potential annual fecundity of dover sole, *Sole asolea*, from European shelf waters during, *Neth J Sea Res*, 34 (1995) 45–58. doi: 10.1016/0077-7579(95)90013-6

38 Hornell J, Report on the results of a fishery cruise along the Malabar Coast and to the Laccadive Islands, *Madras Fish Bull*, 4 (4) (1910) 76–126.

39 Devanesan D W, A brief investigation into the causes of the fluctuations of the annual fishery of oil sardine of Malabar, *S. longiceps* determinations of its age and an account of the discovery of its eggs and spawning ground, *Madras Fish Bull*, 28 (7) (1943) 1–24.

40 Nair R V, Notes on the spawning habits and early life-history of the oil sardine, *Sardinella longiceps*, *Indian J Fish*, 6 (2) (1959) 342–359.

41 Prabhu M S & Dhulkhed M H, on the occurrence of small-sized oil sardine, *Sardinella longiceps*, *Curr Sci*, 36 (1967) 410–411.

42 Lam T J, Environmental influences on gonadal activity in fish, In: *Fish physiology reproduction behaviour and fertility control*, (Academic Press, Florida), 1983, pp. 65–116.

43 Okuzawa K, Puberty in teleosts, *Fish Physiol Biochem*, 26 (2002) 31–41. doi: 10.1023/A:1023395025374

44 Ahirwal S K, Jaiswar A K & Chakraborty S K, Diet composition of oil sardine, *Sardinella longiceps* (Valenciennes, 1847) from Mumbai waters of Maharashtra, India, *Indian J Geo-Mar Sci*, 47 (09) (2018) 1880-1887.

45 Wright P J & Trippel E A, Fishery-induced demographic changes in the timing of spawning: consequences for reproductive success, *Fish Fish*, 10 (2009) 283–304. doi: 10.1111/j.1467-2979.2008.00322.x