Indian J. Fish., 37 (4) : 335 - 346 (1990)

STUDIES ON THE SPAWNING BIOLOGY OF THE TRENCHED SARDINE, *SARDINELLA SIRM* (WALBAUM), FROM VIZHINJAM, SOUTH-WEST COAST OF INDIA

S. LAZARUS *

Central Marine Fisheries Research Institute, Cochin - 682 031, India

ABSTRACT

Development of ova to maturity and the duration and frequency of spawning indicated that *Sardinella sirm* would spawn not only in spurts but also nonsynchronically. Presence of more than two distinct batches of ova in the ovaries indicated that the fish spawns twice in a season. The spawning season extended from December to February off Vizhinjam. Females attained maturity at a larger size than males. The minimum size at first maturity was found to be 175-179 mm for males and 180 - 184 mm for females. The overall sex-ratio was unequal and females predominated from 105 mm size onwards. Fecundity showed a wide range of variation from 21.5 to 132.9 thousands. The spawning migration of the fish towards the inshore waters off Vizhinjam was observed.

INTRODUCTION

Information on reproductive cycles is essential for a better understanding of the biology of any fish population. There is very little information available on the biology of *Sardinella sirm* (Ronquillo, 1960; Chacko and Gnanamekalai, 1963; Gnanamekalai, 1963 a, b; Lazarus, 1973; Bennet *et al.*, 1986 and Lazarus, 1987 a, b). With a view to supplementing this, a detailed investigation was undertaken at Vizhinjam on the breeding biology of this sardine, and the salient findings are presented here.

MATERIAL AND METHODS

Material for this study was collected from the boat seine, shore seine, gill net, drift net and hooks and line catches landed at Vizhinjam during the period between October, 1975 and April, 1978. Random samples, each consisting of thirty fish, were collected twice a week and data on the length and weight of fish, locality of capture, sex, state of maturity and weight of gonads were recorded. Since the spawning habit has to be studied through indirect methods, the method of analysis of growth of ova by measuring their diameters as developed by Thompson (1915) and successfully employed by subsequent workers like Clark (1925, 1934), Hickling and Rutenberg (1936) and de Jong (1940), was followed. The ovaries were preserved as suggested by Raja (1967). Measurements were taken as described by Clark (1934), June (1953) and Yeun (1955). A total of 600 ova drawn with equal representation from the three regions of both the lobes were examined for frequency distribution. Ova of 0.14 mm size and above were measured for all the stages except stages I and II where ova smaller than that size were also measured.

In order to study the maturity and to ascertain the spawning season, 1,837 females and 1,936 males were examined, and depend-

Present address : Vizhinjam Research Centre of CMFRI, Vizhinjam, Trivandrum , India.

ing on the macroscopic appearance and the microscopic structure of the ova in the females, the stages of maturity were recognised according to the criteria established by the International Council for the Exploration of the Sea (Wood, 1930) and as reproduced by Lovern and Wood (1937). But following Raja (1970) Stage II was sub-divided into IIa and IIb to differentiate between virgin maturing and the spent-resting fish respectively and likewise stage VII into VIIa and VIIb to distinguish respectively between partially and completely spent conditions.

To find the relation between the size of gonads and the length of fish, a total of 239 fish were examined. The sample contained 100 males in the size range 116 - 213 mm total length and 139 females in the size range 113 - 224 mm total length. The gonads in the partially spent and spent fish were not included in the present study. Total length of fish and the length of both the lobes of the gonad were noted for each specimen along with the stage of maturity. Specimens with incomplete tail or with abnormal ovary were also excluded in this study.

For the study of gonado-somatic index (GSI) a total of 264 males and 297 females were considered. The weight of the individuals was first recorded after removing the moisture and other foreign particles. The gonads were then carefully removed and weighed to the nearest mg. Gonado-somatic index in terms of the weight of whole fish was calculated for individual fish, sex-wise and month-wise using the formula; ovary weight x 10^3 / fish weight. The values were then compared with the spawning season of the fish.

Fecundity estimations were made on 300 ovaries of fish ranging in length between 191 and 221 mm. Ovaries in stages IV and V were selected for this purpose as the mature eggs in these ovaries were well separated in their size frequency distribution from the immature stock. The ovaries were preserved in modified Gilson's fluid (Simpson, 1951) for about a month which facilitated liberation of ova from the ovarian tissues. The entire mass of ova was weighed to the nearest 0.0002 g. From this, two sub-samples were taken and each was weighed in an identical manner, and the number of ova were counted under a binocular microscope fitted with micrometer. The fecundity, in this study, is the number of yolked ova multiplied by the weight of the entire mass of ova and divided by the weight of the sample. Two such estimates were made on two sub-samples and the average was taken to represent the fecundity of the fish.

A total of 2,098 specimens in the size range 50 to 234 mm were examined to study the sex-ratio. In fish over 110 mm T. L. it was easy to determine the sex based on the shape of the gonads. But below this size microscopic examination was found necessary in both males and females.

Results and Discussion

Maturity

A stage IV ovary was selected in order to test the distribution pattern of ova. Three portions of the left ovary, i.e., anterior, middle and posterior regions, were removed and teased on microslides. The diameter measurements of ova in each part were noted separately and the frequencies were plotted (Fig. 1a). The frequency curves showed a similar pattern of distribution of the immature, maturing and mature ova. Similarly, the distribution of ova in the right ovary was also found to be uniform. The frequencies from all the three regions of one ovary were then pooled and plotted (Fig. 1b). The same type

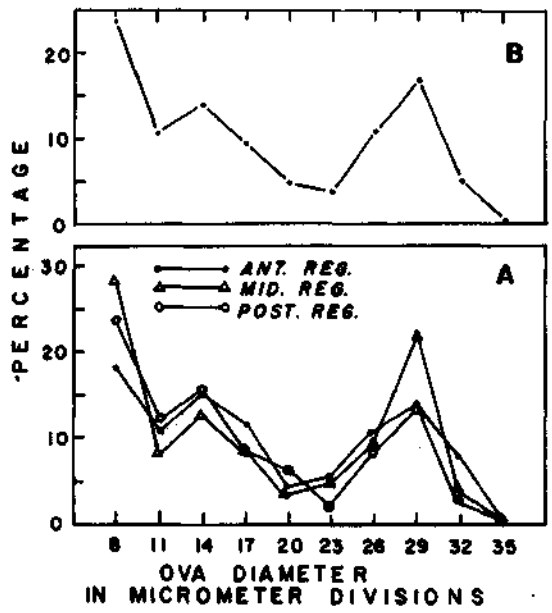

Fig. 1. A. Ova diameter frequency polygons of the anterior, middle and posterior regions of mature ovary of *S. sirm* (1 m.d. = 0.0196 mm).
B. Combined ova diameter frequency polygons of the three regions.

of distribution of ova was apparent in the three different portions.

The ova diameter frequency polygon of a mature ovary (Fig. 1b) showed the presence of three distinct groups of ova. The first group, which might be termed the immature stock, ranged in size upto a maximum of 0.22 mm. The second group, which might be called the maturing ova ranged in size between 0.22 and 0.45 mm. The third group of ova, which were considered to be mature, measured more than 0.45 mm. Ova diameter measurements of as many as 100 ovaries in different stages of maturity showed three groups of ova depending on their stage of maturity. Based on characteristic macroscopic appearance and microscopic study of the ova, nine stages of maturity were defined. Typical ovaries of the nine stages were selected and the ova diameter frequency polygons of these ovaries were drawn (Fig. 2 A to I). In the case of *Sardinella longiceps* also, rather a similar maturity scale was followed by Raja (1970).

Spawning

An examination of the ova diameter frequencies of mature ovaries of *S. sirm*, indicated that they contained in the early stages of maturation at least three groups of ova (Fig. 2D) which could not be sharply differentiated. As the fish approach the spawning season, the mature group of eggs appeared to grow at a faster rate and got distinctly separated off from the maturing group of eggs (Fig. 2 G) and another group which has undergone about half the maturation process immediately following it, leading to two spawning in a season.

A total of 695 fish were examined during November, 1975 to April, 1976 and 773 fish during October, 1976 to May, 1977 to study the percentage occurrence of gonads in different stages of maturity to delineate the spawning season and the data are presented in Table 1. A comparison of the above data on the maturity of *S. sirm* over two successive years indicated that fish of various maturity stages might be present in any month of the season in any percentage. As may be seen from Table 1, fish with running gonads (stage VI) occurred during January and February or in December during previous season. This proved that the spawning occurred between December and February. This was further supported by the occurrence of young fish of about 10 mm T. L. in February and March at Vizhinjam (Table 2). The high values of gonado-somatic index obtained for these months also testified this fact. The gonado-somatic indices of *S. sirm* from the different months of the year are shown in Fig. 5A and

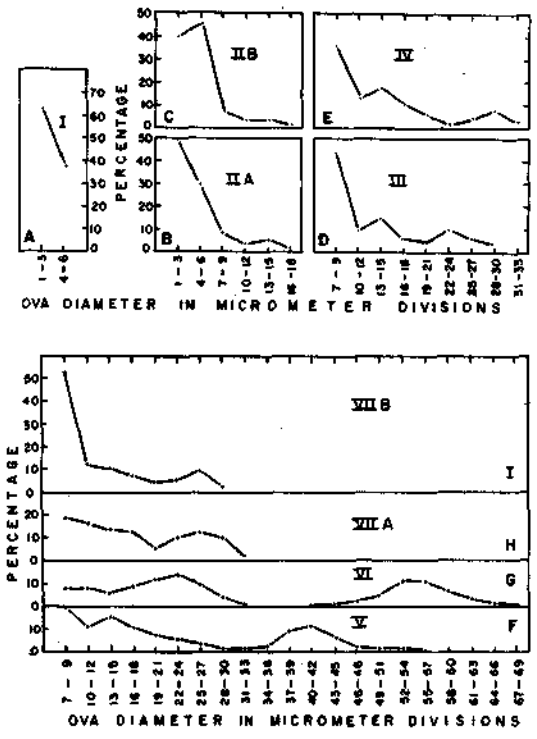

Fig. 2 A to I. Ova diameter frequency polygons of the ovaries of *S.sirm* in various stages of maturity (1 m.d. = 0.0196 mm) A = Stage I; B = Stage II A; C = Stage II B; D = Stage III; E = Stage IV; F = Stage V; G = Stage VI; H = Stage VIIA, I = Stage VIIB.

the percentage occurrence of spawners in different months during the season 1975 -'76 is given in Fig. 5 B in order to confirm the spawning period. From the values representing the average ovary weight and testis weight for different months, it may be seen that the gonad index was low during the period from October to December and also from March to April. For the rest of the period, the values showed a prominent peak, especially in February. The high values revealed high gonadial activity during the periods by both the sexes. Dominance of ripe, running and partly spent specimens during the months, January and February also well supported this view. Thus it could be said that in *S. sirm* spawning took place during the period December to February off Vizhinjam, with active spawning during the last two months.

The multiplicity of modes in the mature ovary of *S. sirm* indicated that they spawn more than once in a season. Ova diametre frequency polygons of ripe ovaries (Fig. 2) indicated two distinct batches of ova; one fully ripe, ready for spawning and the other maturing opaque ova. After the spawning of the first batch of ova, the second batch activated its growth, the spawning of which takes place shortly as explained earlier. The remaining ova of the second batch found in stage VII B ovaries might have also spawned out as there was no evidence of resorption of these ova in the ovaries. The above facts were further supported by the presence of multiple modes among the younger size groups (indeterminate class) as clearly seen in the scatter diagram given by lazarus (1987 b). The extrapolated diagram indicates a maximum time gap of about one and a half months between the spawning of the first two batches and this period is actually the time taken by the second batch of ova to be spawned. The weal brood must be the product of the spawning of the ova which were part of the second batch which lag behind in growth, but subsequently triggered into growth. The presence of minor modes between the two growth lines representing the growth of the product of the two batches of ova is an indication that spawning takes palce not only in spurts, but also nonsynchronically. Length frequency studies (Lazarus, 1987 b) also indicated that a given year class is comprised of two broods; a first major brood released during the peak spawning season between December and February, and a second week brood which appeared to have been released

TABLE 1. *Percentage occurrence of gonads of* S. sirm *in different stages of maturity during the period November, 1975 - April, 1976 and October, 1976 to May, 1977 (combined)*

Month	No. of fish	Sex	Stages of maturity								
			I	IIa	IIb	III	IV	V	VI	VIIa	VIIb
Oct.	83	M	97.6	2.4	-	-	-	-	-	-	-
	67	F	77.6	22.4	-	-	-	-	-	-	-
Nov.	91	M	91.1	8.9	-	-	-	-	-	-	-
	119	F	58.3	41.0	-	0.7	-	-	-	-	-
Dec.	188	M	71.2	20.6	1.5	3.4	-	-	-	-	3.3
	193	F	48.8	40.6	4.2	0.5	-	-	-	-	5.9
Jan.	105	M	14.1	4.5	-	37.7	7.2	9.5	2.1	24.9	-
	122	F	12.3	19.2	4.1	2.4	1.0	8.2	7.5	13.3	32.0
Feb.	127	M	-	6.9	-	47.6	27.6	6.6	1.7	4.0	5.6
	83	F	0.9	18.4	3.9	1.0	5.2	14.8	8.0	32.3	15.5
Mar.	56	M	4.9	58.3	-	30.9	4.9	1.0	-	-	-
	81	F	-	64.1	2.1	15.4	10.4	-	-	8.0	-
Apr.	81	M	46.1	44.5	-	6.3	3.1	-	-	-	-
	39	F	73.0	17.3	1.9	7.8	-	-	-	-	-
May	16	M	50.0	43.8	-	6.2	-	-	-	-	-
	16	F	100.0	-	-	-	-	-	-	-	-

M = Male; F = Female.

TABLE 2. *Occurrence of spawners and spent fish, planktonic eggs and larvae and juvenile of* S. sirm *at Vizhinjam*

Stages	Seasons		
	1975 - '76	1976 - '77	1977 - '78
Spawners	January February	December January	January
Spent	-	December	January
Planktonic eggs	January	-	January
Planktonic larvae	January	-	February
Post larvae and Juveniles	February March April	February March	February March

around September - October months. The time gap between the two broods seems to be approximately 7 months. Clark (1934) demonstrated multiple spawning in the case of *Sardinops coerulea*.

Gnanamekalai (1963 a) while studying the age and growth of *S. sirm* from Tuticorin, reported successive spawning for this fish in a single spawning season. According to her there was one spawning period for every three months, in November-December and February-March in the fishery period and May-June and August-September in the off-season. As reported by her, the spawning took palce when the fish were 140-150 mm, 170-180 mm and 200-210 mm in length (the last range is given as 120-210 mm in her work

which may be a mistake). The present study did not agree with most of her conclusions. Ova diameter studies did not show either a successive spawning behaviour or a spawning once in three months for this fish. More strikingly, spawner below the size of 190 mm was never observed during the course of the present study. It is worth mentioning here that during this long-term study, the fish upto 180 mm were always found to be immature. Mature to spawning fish occurred during November to March with the frequency of occurrence increasing during January and February (Table 1). During this period, spawners, planktonic eggs and various stages of planktonic larvae were collected from the inshore region and a good number of post-larvae and juveniles were also available in the shore seine (*nonna vala*) catches operated within the bay region (Table 2), all indicating that the inshore waters of Vizhinjam provided an ideal spawning ground for this fish.

In view of the absence of mature adults in the fishery off Tuticorin, Chacko (1956) suggested the possibility of *S. sirm* breeding in the offshore region. But the present study revealed that the fishery for this species was supported not only by mature fish but also by spawners, postlarvae and juveniles. The fishery season starts in this area by October normally with the occurrence of fish above 170 mm T. L. Within a very short period they attain sexual maturity and spawn by December to February and the adult individuals are available in the catches upto March/April. In April/May the fishery is supported by juveniles, that is, the broods effect spawning. After March/April the whereabouts of adult fish are not traceable. This phenomenon indicates a spawning migration towards the inshore region when the fish is about to reach sexual maturity.

Relation between the size of gonads and size of fish

It was generally found that the size of the gonad increased with the length of fish in both males and females of *S. sirm*. It was also found that the right lobe of both the gonads was normally shorter and smaller than the left lobe. In order to find out the relationship, the total length of fish was plotted against the length of right and left lobes of testes separately in scatter diagram (Fig. 3A and B). Similarly total length was plotted against the length of right and left lobes of ovaries separately in scatter diagram (Fig. 4A and B). In all cases a curvilinear relationship was observed and the same was fitted for both males and females. The calculated equations are given below.

Male right lobe : $Y = 0.002809 \times^{1.7714}$

Male left lobe : $Y = 0.004582 \times^{1.7092}$

Female right lobe : $Y = 0.00007098 \times^{2.5237}$

Female left lobe : $Y = 0.0001260 \times^{2.4421}$

Gonado-somatic index

Monthly trends in the gonado-somatic index are given in Fig. 5A. High values are seen for both males and females in the months of January and February, coinciding with the months of spawning (Fig. 5 B). From November to February there is an increase in the gonado-somatic index values. This suggests that the increase in gonad weight is associated with the progress of maturity in this species (Table 1). According to James (1967), the gonado-somatic index varied significantly between months in fish with short spawning period. The spawning period for *S. sirm* was short and extended for two months between December and February. High values obtained for January and February in the present study agreed with the above inference.

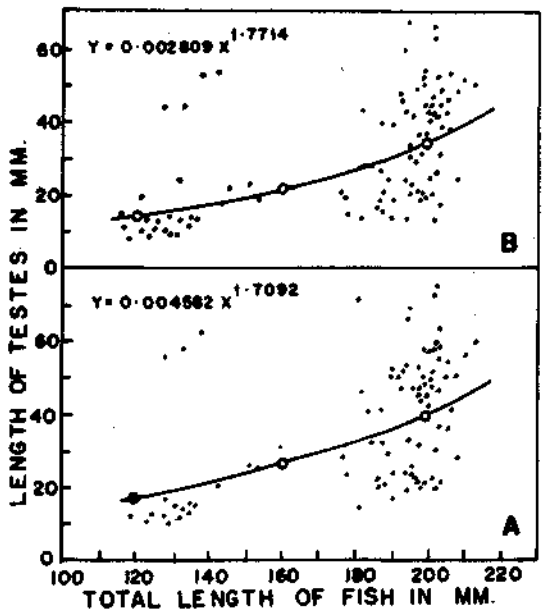

Fig. 3. Relation between length of fish and length of testes in *S. sirm* (A) left lobe and (B) right lobe.

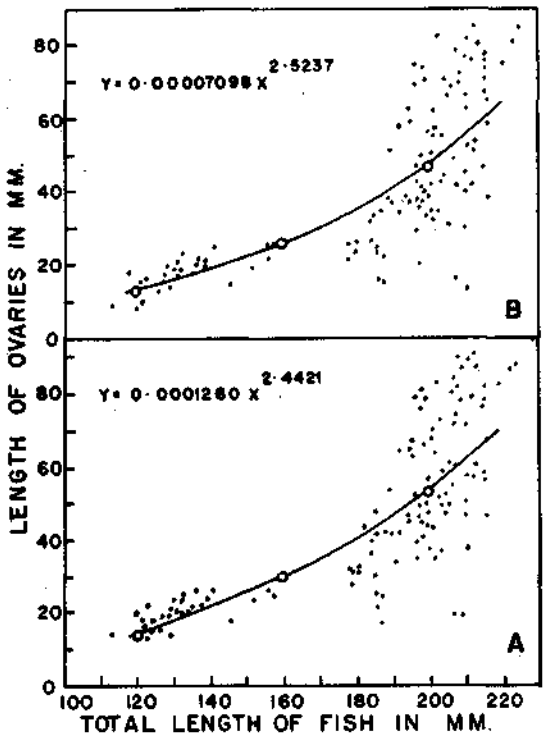

Fig. 4. Relation between length of fish and length of ovaries in *S. sirm* (A) left lobe and (B) right lobe.

Size at first maturity

The minimum size at which *S. sirm* attains maturity was determined from the examination of 941 males ranging in length from 105 to 222 mm and 1,025 females ranging in length from 95 to 230 mm. Fish were grouped sex-wise into 5 mm group and the percentage occurrence of fish of various maturity stages in the size groups was calculated. For the purpose of calculating the size at first maturity, fish belonging to stage III and above were grouped under mature fish. Data for each sex and season were treated separately. Free hand maturity curves (Fig. 6) were drawn to the scatter plots of the percentage of mature fish against fish length so as to estimate the size at which 50 per cent of the fish are mature.

From the maturity curve it is seen that 50% of males were mature at 197 mm length

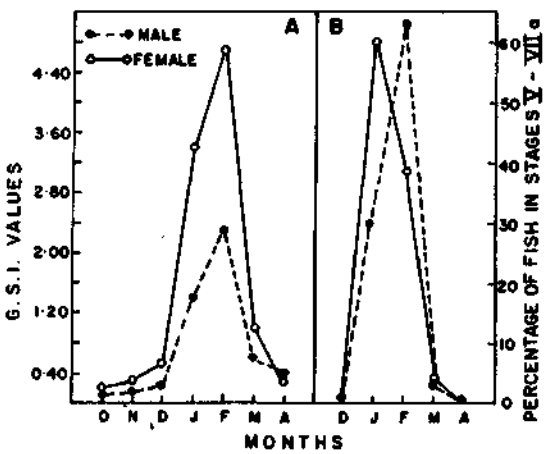

Fig. 5. A. Monthly trends in gonado-somatic index in *S. sirm* B. Percentage occurrence of spawners (Stages V to VIIA) during the season, 1975-76.

and 50% of the females attained maturity at 207 mm length. From Fig. 6 it may be noted that compared with females, males matured at a smaller length. This difference in the length at maturity between sexes is clearly seen from the combined data for the three seasons which show that 50% of males and females were mature at lengths of 197 and 207mm respectively (Fig. 6 D and H). While comparing the maturity curves of females for the three years (Fig. 6 E - G) it could be seen that in the year 1975 - '76, 50% maturity was at 212 mm length, while for the other two years it was at 207 mm (1976 - '77) and at 222 mm (1977 - '78) lengths. But in no season during the study period it was at 197 mm as in the case of males. From this it is clear that the females of *S. sirm* mature at a greater length than the males. In majority of fishes, males have been found to mature at a smaller length than females (Royce, 1972). Mature gonads above 215 - 219 mm size group in the case of male and above 220 - 224 mm in the case of female were available only during 1975 - '76 season. So, while plotting the average maturity curve (Fig. 6 D and H) they get a poor representation (25% for male and below 40% for female) in the respective size group.

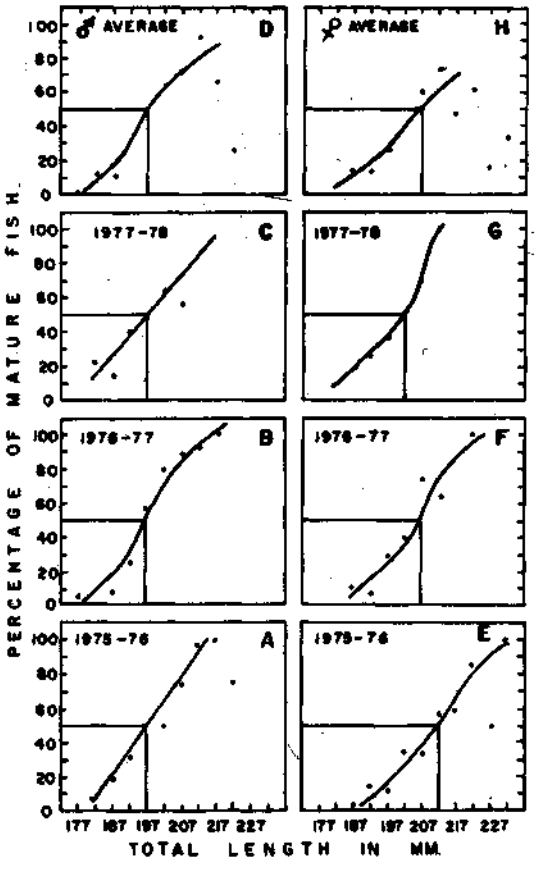

Fig. 6. A to D. Size at first maturity in males of *S. sirm*. E to H. Size at first maturity in females of *S. sirm*.

Fecundity

The data given in Table 3 show that the fecundity of *S. sirm* on the given length range varies from 21.5 to 132.9 thousand with an average of 54.7 thousand. The fecundity observations were plotted against the length of the fish (Fig. 7A), weight of the fish (Fig. 7 B), length of the gonad (Fig. 7 C) and weight of the gonad (Fig. 7 D) in order to find out whether any relation exists between the above parameters and the number of eggs produced. For many, in general, the number of eggs increased with the length and weight of

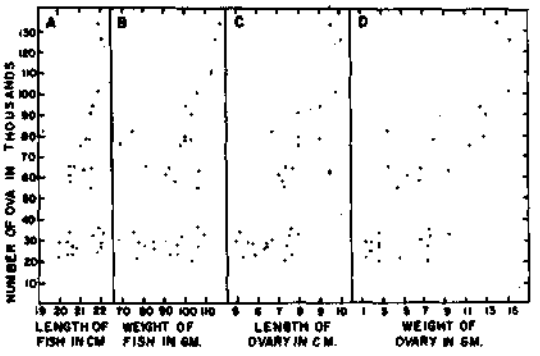

Fig. 7. Relation between fecundity and (A) length of fish, (B) weight of fish, (C) length of ovary and (D) weight of ovary in *S. sirm*.

TABLE 3. *Data on length and weight of fish, length and weight of gonad and fecundity in* S. sirm

Length of fish (cm)	Weight of fish (g)	Length of ovary (cm)	Weight of ovary (g)	Total number of mature ova (in thousands)
21.2	107.00	9.5	9.39	62.7
20.8	86.00	6.3	1.88	25.3
22.0	95.50	5.7	2.70	28.4
20.6	81.50	6.4	2.50	27.2
19.9	77.00	5.3	1.45	21.5
20.4	93.00	5.9	1.40	22.6
20.5	96.00	7.6	4.55	23.1
22.1	109.25	8.0	9.48	33.1
21.9	106.50	7.5	7.63	35.4
22.0	106.50	6.5	7.38	27.3
21.8	103.00	7.7	7.30	20.4
20.4	85.00	5.0	2.33	29.3
20.5	75.75	5.1	2.70	33.5
19.1	68.00	6.0	6.68	30.0
21.6	98.25	5.4	7.52	32.1
20.0	78.25	5.5	1.55	28.9
21.9	117.00	9.6	14.22	132.9
21.9	106.00	9.8	15.16	100.9
20.5	95.00	7.2	6.64	58.2
21.5	93.00	7.7	6.76	64.3
21.5	105.50	7.3	4.52	55.1
20.6	81.50	7.4	3.82	64.6
21.4	103.00	9.0	8.04	77.5
21.3	100.00	8.0	12.71	78.5
19.3	75.00	6.7	3.55	82.2
21.0	97.50	8.0	11.53	75.3
20.5	90.50	7.0	5.53	60.5
21.5	103.00	8.5	13.04	90.4
21.6	106.00	9.0	12.62	94.3
22.0	115.00	10.0	15.41	125.3

the fish and length and weight of the gonad. However, it was also known that the fecundity of individual fish of the same length and weight having the same ovary length and weight might vary considerably.

Ratio of sexes in the commercial catches

Though the material examined covered a wide size range, it was not possible to detect any external characters for sex determination except in the case of ripe females in which case the sex could be assessed based on the size of the belly and also on the heavyness of the body. The sex-ratio of *S. sirm* was generally found to be unequal in the commer-

cial catches, females outnumbering males (Fig. 8). Chacko (1956) found females to be always more than males in the catches off Tuticorin region with male-female ratio of 1:2. There is no regular pattern in the sex ratio also. During the three years of observation, males outnumbered the females only in the 1975 - '76 season. This feature was not seen in all the months (Table 4). There was no differential behaviour of sexes in this species as there was no segregation of sexes. The largest indeterminate examined measured 104 mm. The largest male and female measured 224 and 234 mm respectively. The sex-ratio in different length groups are presented in Table 5. The mean sex ratio for the whole period was 5.58% ID : 45.33% M : 49.09% F with the females dominating.

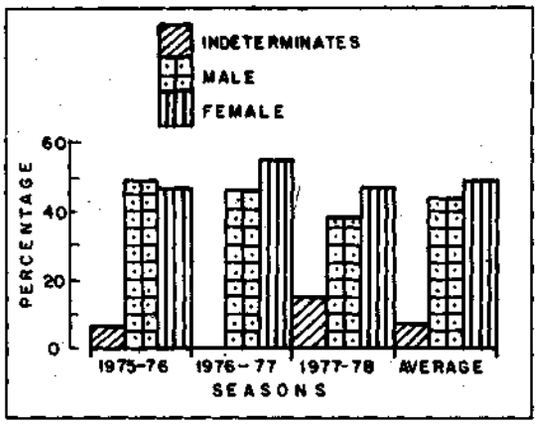

Fig. 8. Sex-ratio of *S. sirm* for the periods, 1975-'76 to 1977-'78.

ACKNOWLEDGEMENTS

The author is grateful to Dr. E. G. Silas, the former Director and Dr. P. S. B. R. James, the present Director, CMFR Institute, Cochin for encouragements, Dr. M. D. K. Kuthalingam, former Head, Pelagic Fisheries Division of CMFRI, for guidance and Dr. M. Devaraj, Dean, Fisheries College Tuticorin for critically going through the manuscript.

TABLE 4. *Sex ratio of S. sirm in the commercial catches, October, 1975 to April 1978.*

Month	1975-'76				1976-'77				1977-'78			
	Total No. of fish	% of ID	% of M	% of F	Total No. of fish	% of ID	% of M	% of F	Total No. of fish	% of ID	% of M	% of F
Oct.	-	-	-	-	150	-	55.33	44.67	30	-	43.33	56.67
Nov.	90	-	46.67	53.33	120	-	40.83	59.17	60	-	43.33	56.67
Dec.	130	-	54.44	45.56	201	-	44.78	55.22	110	46.36	30.91	22.73
Jan.	107	-	31.78	68.22	120	-	59.17	40.83	79	-	48.10	51.90
Feb.	120	-	74.17	25.83	90	-	42.22	57.78	64	56.25	18.75	25.00
Mar.	108	-	47.22	52.78	30	-	20.00	80.00	180	-	31.67	68.33
Apr.	90	33.33	37.78	28.89	30	-	56.67	43.33	107	-	49.53	50.47
May	-	-	-	-	32	-	50.00	50.00	-	-	-	-
Mean		5.56	48.67	45.77			46.13	53.87		14.66	37.94	47.40

ID = Indeterminate; M = Male; F = Female.

TABLE 5. *Ratio of indeterminate, male and female* S. sirm *in different length groups*

Size Group	Number of fish	Indeterminate	Male	Female
50 - 54	1	100.00	-	-
55 - 59	-	-	-	-
60 - 64	3	100.00	-	-
55 - 69	15	100.00	-	-
70 - 74	30	100.00	-	-
75 - 79	19	100.00	-	-
80 - 84	7	100.00	-	-
85 - 89	3	100.00	-	-
90 - 94	8	100.00	-	-
95 - 99	22	95.45	-	4.55
100 - 104	12	83.33	-	16.67
105 - 109	1	-	100.00	-
110 -114	13	-	38.46	61.54
115 - 119	30	-	40.00	60.00
120 - 124	73	-	43.84	56.16
125 - 129	92	-	53.26	46.74
130 - 134	93	-	47.31	52.69
135 - 139	54	-	40.74	59.26
140 - 144	25	-	40.00	60.00
145 - 149	20	-	55.00	45.00
150 - 154	18	-	27.78	72.22
155 - 159	11	-	27.27	72.73
160 - 164	6	-	50.00	50.00
165 - 169	10	-	60.00	40.00
170 - 174	34	-	61.76	38.24
175 - 179	99	-	69.70	30.30
180 - 184	174	-	58.62	41.38
185 - 189	199	-	55.28	44.72
190 - 194	206	-	48.54	51.46
195 - 199	214	-	49.07	50.93
200 - 204	119	-	51.26	48.74
205 - 209	161	-	41.61	58.39
210 - 214	126	-	34.92	65.08
215 - 219	85	-	28.24	71.76
220 - 224	28	-	14.29	85.71
225 - 229	6	-	-	100.00
230 - 234	1	-	-	100.00
50 - 104	120	97.80	-	2.20
105 - 164	436	-	45.18	54.82
165 & above	1542	-	48.90	51.10
Mean	-	5.58	45.33	49.09

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