SOME ASPECTS OF SPAWNING BIOLOGY OF INDIAN OIL SARDINE *SARDINELLA LONGICEPS* VALENCIENNES

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INTRODUCTION

Although Hornell (1910) made a few observations on the spawning habits and migratory movements of Indian oil sardine, *Sardinella longiceps*, the first concerted attempt to understand its maturity and spawning habits and to delimit the spawning season can be said to have been made by Hornell and Nayudu (1924). Following this, Devanesan (1943), while confirming some of the earlier findings, also contradicted certain others. Later, Nair (1953 & 1959), giving a detailed review of earlier investigations, did not agree with some of the observations of previous workers in addition to providing more information to our knowledge on the spawning habits of oil-sardine based on his study from 1948 to 1955. Since these authors had to divide their attention not only to administrative problems but also to various other aspects of biology of the fish at the same time, it is but natural that conclusions have been drawn with limited data at their disposal. Since it is well known that a fishery which is dependent on a few age classes is much more affected by the success or failure of spawning in any one year than which operates on many age groups and in view of the fact that determination of the spawning season and frequency of reproduction within the season and within the life span of the fish are essential prerequisites in assessing the reproductive potential of a population, it is necessary that contradictory views expressed by earlier workers are thoroughly analysed and a more precise information is obtained to formulate future programme of work. With the expanding activities of Central Marine Fisheries Research Institute, the author was given an opportunity to concentrate solely on this problem of maturity and spawning habits and the results of his investigation based on five spawning seasons from 1959 to 1963 at Calicut are herein reported.

METHODS

Random samples each consisting of twentyfive fish were drawn normally twice a week from local fish landing place. As and when necessary, samples from market arrivals were also taken. The date, length and weight of the fish, locality of capture, sex, state of maturity and weight of gonads were recorded. Since the problem of spawning habits has to be largely approached by such

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indirect method like the analysis of growth of ova by measuring their increasing diameters, the method, as developed by Thompson (1915) and successfully employed by subsequent workers like Clark (1925 & 1934), Hickling and Rutenberg (1936) and De Jong (1940) to mention a few, was followed. While the practice of earlier workers has been to preserve the ovaries in 10% formalin, some of the later workers have reduced the strength to 5%. But during this study, it was found that even 5% formalin was too strong for, as a result of preservation, there was large amount of distortion in the ova to odd shapes rendering it difficult to correctly assess the diameter even though the measurements were taken on the lines of earlier workers. De Jong (*loc. cit.*) pointing out the disadvantage of this method opined that due to asymmetry of eggs after preservation, the difference between two groups of eggs appeared less than they were in reality, for, the largest diameter of an ovum of the group of younger ova exceeded the smallest diameter of an ovum of the older group. Further, it was noticed during the present study that 5% formalin hardens the material too much, rendering it a bit tedious to tease out the individual ova from the ovigerous lamellae. Hence, weaker strengths of formalin of 4%, 3% and 2% were tried and it was found that 2% formalin was ideal both for proper preservation with minimum distortion and for easier removal of ova. In addition to this, at the time of examination a drop of Gilson's fluid with double the amount of glacial acetic acid (*i.e.*, 18 cc instead of 9 cc in normal Gilson's fluid) placed on the material facilitated more rapid and easier separation of intra ovarian eggs. The method of measurement was in general similar to that described by Clark (1934), June (1953), Yuen (1955) and others by having the micrometer permanently fixed in horizontal position and taking the diameter parallel to two horizontal guide lines on the slide in whatever axis the ovum lies by moving the slide slowly. The parallel guide lines prevented duplicate measurements of the same ovum. Thus, the diameter of the ovum may be defined as the distance between two parallel lines running along the two extremities of the ovum perpendicular to the guide lines.

Distribution of ova within an ovary

Although Nair (1959) has stated that there were no differences in the distribution of the maturing and mature eggs either in the different regions of the same ovary or in the two ovaries of the same fish, in view of the qualitative nature of this statement and in order to subsample an ovary with confidence, it was decided at the outset to statistically test the distribution of ova of various sizes throughout an ovary as well as differences, if any, between the right and left ovaries. The procedure adopted was similar to that described by Yuen (*op. cit.*) and Otsu and Uchida (1959). Thin cross sections were taken from the anterior, middle and posterior regions of the left member of one of the mature ovaries in the collection and labelled A, M and P respectively. Each of these samples was further subdivided into three subsamples named 1, 2 and 3 representing respectively the periphery, mid-region and centre of the ovary. Thus for each section, there were three positions totalling 9 subsamples, A_1, A_2 A_3, M_1, M_2, M_3, P_1, P_2 and P_3. These subsamples were weighed to the nearest 0.0002 gm. and all the ova from 20 micrometer divisions above were measured. This procedure was adopted every year before analysis of ovaries for ova diameter measurements was taken up. The weights and diameter measurements are given in Tables I to V representing the years 1959 to 1963.

Analysis of variance for any difference in the frequency distribution for each of these ovaries (Table VI) showed significant differences at 5% level between sections for the ovaries taken for 1959 and 1962 only. There was no significance in the ovaries taken for the other years nor was there any significance at 5% level between positions within sections in any year. It was not determined whether the differences between sections in 1959 and 1962 were real but it may not be due to artifact of preservation for, such a significance was not seen in the material of other three years. Taking year-wise to find whether there were any interesting features in the mean ova diameter for different sections and positions, it is seen that for 1959 sample, the mean diameter for sections A, M and P were 0.5236, 0.5322 and 0.5425 mm. respectively *i.e.*, longest mean diameter for the posterior region. Within the sections, largest mean diameter was found in the periphery for section A and in the mid-region for M and P (Table I). For 1960, the mean diameter for the three respective sections were 0.4881, 0.4834 and 0.4888 mm., again the posterior region carrying the largest mean diameter. Within the sections, while the mean diameter was largest in the centre for A, it was located in periphery for M and P (Table II). The mean diameter in the sample for 1961 were 0.5762, 0.5751 and 0.5864 mm. respectively which showed similarity to the previous two years in having the largest diameter in the posterior region. The positions where largest mean diameters were found differed among the sections for, while largest was found in periphery for A, for M it was mid-region and for P it was centre (Table III). For 1962, unlike the previous three years, the anterior region carried the largest mean diameter, for the measurements were 0.5471, 0.5274 and 0.5396 mm. Among the sections, largest was found at the periphery for A and M and at the mid-region for P (Table IV). In 1963, the middle position had the largest mean ova diameter with 0.5482 mm. whereas for A and P the diameters were 0.5371 and 0.5447 mm. Largest mean diameter was found at the periphery for A and M but at the centre for P (Table V). Comparing the entire data, it is thus seen, that there was lack of uniformity between the years in the largest mean diameter both between the sections as well as between the positions. However some broad generalisations can be made as for instance, the mean diameter was largest in the posterior region. Although this was clear only for the first 3 years, even for the subsequent two years, the differences between the mean diameter of the posterior region and the region which had the largest

TABLE I

Frequency distribution of diameters of all ova of 20 micrometer divisions and above from the various parts of the ovary

(28-9-1959; Fish length =174 mm.)

Diameter in micrometer divisions	A_1	A_2	A_3	M_1	M_2	M_3	P_1	P_2	P_3
20	7	8	5	5	2	11	9	3	3
21	2	3	4	3	4	4	0	1	4
22	5	4	6	5	3	4	8	0	7
23	2	7	3	7	6	6	3	1	4
24	6	4	4	4	3	3	5	6	4
25	10	8	5	4	3	5	10	4	1
26	1	2	2	3	5	7	1	4	8
27	2	6	3	6	5	3	4	0	8
28	4	2	2	4	5	6	4	3	2
29	5	2	2	4	4	7	3	8	1
30	8	13	14	7	12	25	11	11	12
31	1	3	4	5	6	14	4	16	6
32	5	10	5	7	11	9	11	13	12

33	5	6	1	13	8	13	8	10	13
34	5	6	6	5	4	5	5	5	5
35	8	11	11	6	9	8	10	7	15
36	0	2	1	5	5	3	2	4	4
37	5	1	1	2	0	0	0	1	6
38	0	2	0	1	3	0	1	1	1
39	2	0	0	1	2	0	2	0	0
40	1	1	0	1	1	0	0	1	0
41	0	0	0	0	0	0	1	0	0
42	1	0	0	0	0	0	0	0	1
TOTAL	85	101	79	98	101	133	102	99	117
Mean diameter	28.94	28.82	28.51	29.26	29.91	28.72	28.89	30.44	30.09
Sample weight (gm).	0.0152	0.0162	0.0134	0.0158	0.0170	0.0182	0.0166	0.0168	0.0174
Calculated no. of ova for 0.1 gm weight	559	623	589	620	594	731	614	589	672

TABLE II

Frequency distribution of diameters of all ova of 20 micrometer divisions and above from the various parts of ovary

(18-8-1960; Fish length=181 mm.)

Diameter in m.d.	A_1	A_2	A_3	M_1	M_2	M_3	P_1	P_2	P_3
20	10	6	9	9	14	11	6	9	12
21	1	1	4	3	4	4	0	2	1
22	5	6	2	2	6	7	2	3	6
23	5	5	2	4	2	6	2	6	1
24	4	6	5	4	2	5	6	5	6
25	18	8	14	13	12	13	11	12	8
26	7	10	6	6	5	11	9	5	7
27	7	12	4	17	13	14	7	16	10
28	14	15	13	12	10	14	12	9	16
29	9	9	9	7	11	6	14	9	6
30	17	17	19	14	18	22	25	12	20
31	8	2	3	10	6	1	3	6	3

32	3	2	2	1	3	4	3	1	1
33	1	2	1	2	3	0	1	0	2
34	1	0	3	1	3	0	0	1	0
35	0	2	1	0	0	0	0	1	2
TOTAL	110	104	97	105	112	118	101	97	101
Mean diameter	26.70	26.87	26.91	26.82	26.72	26.19	27.39	26.47	26.68
Sample weight (gm.) . . .	0.0108	0.0128	0.0112	0.0126	0.0126	0.0128	0.0112	0.0110	0.0108
Calculated no. of ova for 0.1 gm. weight	1019	813	866	833	889	922	902	882	935

TABLE III

Frequency distribution of diameters of all ova of 20 micrometer divisions and above from various parts of ovary

(14-8-1961; Fish length = 159 mm.)

Diameter in m.d.	A_1	A_2	A_3	M_1	M_2	M_3	P_1	P_2	P_3
20	8	4	10	8	8	6	4	5	3
21	3	4	3	3	1	3	2	4	2
22	3	6	3	3	3	4	4	5	5
23	2	4	1	1	3	1	3	2	5
24	3	4	1	4	4	3	2	4	0
25	5	7	7	7	5	10	8	6	4
26	6	2	1	1	2	1	6	3	0
27	3	4	5	2	1	0	6	2	5
28	0	2	6	4	4	4	2	0	2
29	1	2	1	2	0	3	2	6	2
30	1	1	3	1	3	4	8	4	2
31	0	2	3	4	5	3	4	2	0
32	3	3	4	4	2	4	2	5	5

33	5	4	3	7	8	6	3	6	5
34	6	3	3	8	8	6	4	7	3
35	11	12	13	14	9	9	12	13	9
36	9	5	10	3	10	7	11	9	9
37	9	12	9	8	9	9	7	9	9
38	6	2	4	3	4	4	3	7	5
39	7	9	5	8	4	7	5	6	10
40	5	6	5	3	4	5	7	5	9
41	2	1	1	0	1	1	2	0	2
42	3	1	0	2	0	0	1	0	4
43	0	0	0	0	1	1	1	0	0
44	1	0	0	1	0	0	0	0	0
TOTAL	102	100	101	101	99	101	109	104	100
Mean diameter	32.23	31.49	31.26	31.54	31.65	31.61	31.68	31.81	33.25
Sample weight (gm.)	0.0118	0.0102	0.0124	0.0116	0.0112	0.0112	0.0144	0.0122	0.0126
Calculated no. of ova for 0.1 gm. weihgt	864	980	815	871	884	902	757	853	794

TABLE IV

Frequency distribution of diameters of all ova of 20 micrometer divisions and above from various parts of ovary

(7-8-1962; Fish length = 181 mm.)

Diameter in m.d.	A_1	A_2	A_3	M_1	M_2	M_3	P_1	P_2	P_3
20	3	9	3	4	6	9	9	7	5
21	0	1	3	6	2	4	2	3	2
22	3	7	1	3	2	2	2	3	2
23	1	1	2	1	2	4	4	2	2
24	2	3	1	5	3	1	3	4	2
25	3	2	6	4	4	4	1	2	6
26	5	1	2	1	4	7	3	0	5
27	7	6	4	2	7	6	7	2	8
28	0	9	4	4	5	7	6	3	4
29	4	2	9	8	6	7	4	4	5
30	14	15	17	12	21	17	19	20	17
31	13	7	12	13	7	7	15	6	14
32	14	7	16	14	14	11	6	17	18

33	6	10	6	11	15	7	9	12	7
34	7	9	7	11	3	4	12	9	6
35	16	10	7	3	3	4	11	6	8
36	2	0	4	2	0	0	2	1	1
37	2	3	1	0	0	0	0	1	3
38	0	0	0	0	1	0	1	0	0
39	0	1	0	0	0	0	0	0	0
40	0	2	0	0	0	0	0	0	0
TOTAL	102	105	105	104	105	101	116	102	116
Mean diameter	30.59	29.57	30.04	29.46	29.20	28.25	29.59	29.71	29.65
Sample weight (gm.)	0.0146	0.0156	0.0144	0.0144	0.0162	0.0140	0.0184	0.0156	0.0172
Calculated no. of ova for 0.1 gm. weight	699	673	729	722	648	721	630	654	674

TABLE V

Frequency distribution of diameters of all ova of 20 micrometer divisions and above from various parts of ovary

(15-7-1963; Fish length = 174 mm.)

Diameter in m.d.	A_1	A_2	A_3	M_1	M_2	M_3	P_1	P_2	P_3
20	4	5	1	2	1	3	1	3	4
21	4	4	5	1	3	1	2	3	5
22	4	3	2	6	0	7	6	3	1
23	4	5	6	7	8	6	3	3	3
24	7	7	6	5	4	2	4	7	7
25	4	12	7	5	9	9	7	9	8
26	5	11	12	5	8	11	7	6	3
27	5	3	6	5	2	6	11	2	7
28	7	5	2	5	1	5	7	9	10
29	0	1	2	6	3	2	0	3	2
30	9	8	6	6	6	4	12	6	5
31	3	5	6	2	5	3	8	4	7
32	5	8	6	4	8	6	3	7	4

33	12	10	10	4	6	7	5	8	9
34	6	8	8	5	6	6	8	5	10
35	14	14	13	9	16	10	9	15	11
36	9	3	6	10	9	8	6	3	7
37	2	1	4	6	3	2	3	7	5
38	1	1	1	5	0	2	2	4	4
39	0	2	0	2	1	2	0	1	2
40	0	0	0	4	0	0	1	0	0
41	1	0	0	1	0	0	0	0	0
42	0	0	0	0	0	1	0	0	0
TOTAL	106	116	109	105	99	103	105	108	114
Mean diameter	29.84	29.08	29.64	30.63	30.22	29.51	29.60	30.05	30.11
Sample weight (gm.)	0.0120	0.0148	0.0132	0.0134	0.0118	0.0132	0.0142	0.0140	0.0144
Calculated no. of ova for 0.1 gm. weight	833	784	826	784	839	780	739	771	792

TABLE VI

Analysis of variance of diameters of all opaque ova from 20 micrometer divisions onwards from different parts of the ovary selected for the years 1959 to 1963

Date & length	Source of variation	D.F.	S.S.	Mean	F	Significance
28-9-1959	Between sections	2	160.88	80.44	3.24	*
174 mm.	Positions within sections	6	224.08	37.35	1.50	N.S.
	Individuals within positions . . .	906	22490.18	24.82	..	
	TOTAL	914	22875.14			
18-8-1960	Between sections	2	16.14	8.07	0.66	N.S.
181 mm.	Positions within sections	6	74.57	12.43	1.01	N.S.
	Individuals within positions . . .	936	11515.25	12.30	..	
	TOTAL	944	11605.96			
14-8-1961	Between sections	2	72.63	36.32	0.89	N.S.
159 mm.	Positions within sections	6	209.23	34.87	0.85	N.S.
	Individuals within positions . . .	908	37182.94	40.95	..	
	TOTAL	916	37464.80			

7-8-1962	Between sections	2	185.99	93.00	5.00	*
181 mm.	Positions within sections	6	137.61	22.94	1.23	N.S.
	Individuals within positions . . .	947	17623.38	18.61	..	
	TOTAL	955	17946.98			
15-7-1963	Between sections	2	63.72	31.86	1.20	N.S.
174 mm.	Positions within sections	6	117.81	19.64	0.74	N.S.
	Individuals within positions . . .	956	25406.46	26.58	..	
	TOTAL	964	25587.99			

D.F.=Degree of freedom; S.S.=Sum of squares; N.S.=Not significant; *=Significance at 5% level.

diameter were not much. In the anterior region, periphery appeared to have the largest mean diameter in 4 out of 5 samples; for the middle region also, periphery accounted for 3 years. No such comparison can be made regarding other positions.

The number of ova to be expected from 0.1 gm of each subsample for each year was calculated (*vide* Tables I to V) and tested by analysis of variance (Table VII) to find out whether there were any significant differences in relative numbers within sections. The results showed that there was no significant difference ($P > 0.05$) in the relative numbers per unit weight of ovary between sections A, M and P. Comparing Tables I to V to see whether there was any regular pattern in the distribution of largest number of ova either within sections or positions, it was found that only at the centre position of posterior region, there was maximum number of ova whereas no uniformity could be deducted elsewhere.

Distribution of ova in right and left ovaries

Another preliminary step in the investigation, as stated earlier was to examine the possible differences between the frequency distribution of diameters of ova in the right and left members of a pair of ovaries. This procedure was also followed for each year. Because there was significance between sections in the frequency distribution in 1959 and later in 1962 also (*vide infra*), the subsampling was done by taking a portion from anterior, middle and posterior regions for all the years. Measurements of all ova with diameter greater than 6 micrometer divisions (hereafter abbreviated as m.d. in the text) were made and recorded in Table VIII which also shows the chi-square test performed to compare the frequency distribution between the right and left ovaries. Whenever degrees of freedom exceeded 30, 't' test was performed. The results showed that there was no significance at 5% level in any of the years which lead to conclusion that the differences between the frequency distribution of right and left ovaries of the same pair are negligible. Thus, the method followed in this study, for the sake of uniformity, was to take portions of ovary from the anterior, middle and posterior regions of left ovary and measure the diameter of ova of 5 m.d. and above. Only for certain ovaries belonging to stages IIa, IIb and VIIb, ova smaller than 5 m.d. were measured.

Required number of ova to be measured

In the beginning of the study a total of 1,000 ova drawn equally from the three regions was measured but during the course of investigation, it was felt whether such a time consuming number was necessary especially in view of large number of ovaries to be examined every year. Although Clark (1934) drew her observations based on measurements of 200 ova, Prabhu (1956) considered that measurement of at least 1,000 ova was necessary to mitigate the

TABLE VII

Analysis of variance for number of ova in different parts of ovary selected for the years 1959 to 1963

Date & length	Source of variation	D.F.	S.S.	Mean	F	Significance
28-9-1959 174 mm.	Between sections . . . . . . Positions within sections . . .	2 6	5110.23 16265.33	2555.12 2710.89	0.94 ..	N.S.
	TOTAL	8	21375.56			
18-8-1960 181 mm.	Between sections . . . . . . Positions within sections	2 6	998.00 28366.00	499.00 4727.67	0.11 ..	N.S.
	TOTAL	8	29364.00			
14-8-1961 159 mm.	Between sections . . . . . . Positions within sections . . .	2 6	14337.56 19534.00	7168.78 3255.67	2.20 ..	N.S.
	TOTAL	8	33871.56			
7-8-1962 181 mm.	Between sections . . . . . Positions within sections	2 6	4268.67 6143.33	2124.34 1023.89	2.07 ..	N.S.
	TOTAL	8	10392.00			
15-7-1963 174 mm.	Between sections . . . . . . Positions within sections	2 6	3520.23 5003.33	60.12 833.89	2.11 ..	N.S.
	TOTAL	8	8523.56			

TABLE VIII

Egg diameter frequencies of right and left ovaries from the same fish for different years with test for significance

Diameter in m.d.	Diameter in mm.	26-8-1959 (171 mm.)		18-8-1960 (179 mm.)		14-8-1961 (156 mm.)		3-8-1962 170 mm.)		22-7-1963 (177 mm.)	
		R	L	R	L	R	L	R	L	R	L
7 . .	0.1274	116	107	114	149	153	156	128	138	186	187
8 . .	0.1456	77	81	83	91	93	72	48	69	80	77
9 . .	0.1638	64	67	57	51	42	54	42	32	64	59
10 . .	0.1820	60	63	54	82	53	62	51	54	66	76
11 . .	0.2002	30	29	30	35	26	27	19	21	30	37
12 . .	0.2184	27	23	45	39	36	27	24	25	29	46
13 . .	0.2366	24	27	35	34	22	20	14	21	34	32
14 . .	0.2548	16	18	28	41	25	10	12	14	21	20
15 . .	0.2730	24	32	51	40	33	25	13	17	48	34
16 . .	0.2912	11	15	17	11	21	24	7	12	34	33
17 . .	0.3094	15	19	11	19	20	22	5	13	24	27
18 . .	0.3276	16	22	10	15	23	21	15	10	28	17
19 . .	0.3458	19	17	22	8	22	21	10	10	26	23

20 . .	0.3640	47	41	17	12	39	27	19	19	20	28
21 . .	0.3822	13	19	2	6	14	11	10	12	18	12
22 . .	0.4004	14	14	8	7	13	17	3	22	10	8
23 . .	0.4186	7	15	9	9	11	11	14	15	8	2
24 . .	0.4368	12	15	19	11	6	7	10	14	9	6
25 . .	0.4550	21	13	25	26	14	9	23	23	6	7
26 . .	0.4732	6	9	25	23	6	6	13	17	3	8
27 . .	0.4914	11	6	41	34	5	9	22	28	4	8
28 . .	0.5096	8	11	39	61	9	5	18	28	10	15
29 . .	0.5278	6	5	43	39	10	5	20	14	16	14
30 . .	0.5460	31	19	88	82	27	28	30	30	34	37
31 . .	0.5642	13	22	33	39	14	22	23	17	40	39
32 . .	0.5824	32	24	27	39	36	44	20	21	38	30
33 . .	0.6006	33	39	14	17	44	38	23	23	30	36
34 . .	0.6188	23	30	3*	7*	43	36	18	14	34	27
35 . .	0.6370	69	88	5*	7*	63	72	50	60	34	37
36 . .	0.6552	31	32	1*	0*	29	46	62	43	14	12
37 . .	0.6734			..	..	29	43	58	45	16	18

TABLE VIII—*contd.*

		R	L	R	L	R	L	R	L	R	L
38 . .	0.6916	20	22	..	..	20	20	57	39	9*	5*
39 . .	0.7098	11	16	..	..	15	14	41	29	1*	5*
40 . .	0.7280	1*	8	..	..	11	7	47	36	2*	1*
41 . .	0.7462	4*	0*	..	..	3*	4*	25	20	..	..
42 . .	0.7644	3*	1*	..	..	2*	2*	17	10	..	..
43 . .	0.7826	1*	0*	..	..	2*	0*	5*	9*	..	..
44 . .	0.8008	..	..	..	..	..	..	5*	5*	..	..
45 . .	0.8190	..	..	..	..	..	..	6*	4*	..	..
46 . .	0.8372	..	..	..	..	..	..	0*	4*	..	..
47 . .	0.8554	..	..	..	..	..	..	0*	2*	..	..
TOTAL		970	1002	956	1034	1029	1024	1027	1039	1026	1021
Degrees of freedom . .			33		27		34		36		31
Chi-square			29.611		38.806		34.209		51.696		24.956
't'			0.37		..		0.09		1.73		0.74
Significance at 5 % level. .			N.S.		N.S.		N.S.		N.S.		N.S

*Pooled together because of low frequencies.

probable error in the representation of various groups of ova. Buñag (1956) was of opinion that at least 2,000—2,500 ova to be measured in the advance maturing and mature ovaries. However, in the investigations involving examination of large number of ovaries, workers seem to have resorted to measuring lesser number of ova, roughly from 100 to 300 (June, *op. cit.*, Yuen, *op. cit.*, Howard and Landa, 1958). So, it was decided to test whether there can be any serious error if the number of ova measured is reduced to 300. About 330 ova from each of the three regions were measured to total up 1,000 for the entire ovary for 6 ovaries representing maturing, mature, partially spent and completely spent phases and the frequency distribution was worked out. Then measurements of first 100 ova from each region were tabulated and the frequency distribution of these 300 ova were compared with that of 1,000 ova. The ova diameter frequencies are given in Table IX for the six different ovaries along with the result of chi-square test. It is seen that none of the ovaries showed any significance at 5% level. So, later in the study a total of only 300 ova drawn with equal representation from the three regions was examined for frequency distribution. In the following pages, for easier presentation, the diameter of ova is described in micrometer divisions. Each m.d. is equivalent to 0.0182 mm.

The stages of maturity mentioned in this paper are according to the criteria established by the author earlier (Antony Raja, MS. z). A sign of + after the numeral for certain maturity stages indicates that the particular ovary is slightly advanced from the stage preceding the sign.

OBSERVATIONS

Ova Diameter Frequency

Since a large number of ovaries were examined and presentation of results of which may be unweildy, only a selected few are presented in the respective tables from which those with characteristic features showing progressive growth of ova through different stages have been taken to plot the figures. The ova diameter frequencies of each year are considered separately first which is followed by a description of a composite picture representing all the stages from early maturing to spent resting phases. In the tabulated data and in the figures, measurements are given in class intervals of two micrometer divisions.

1959

Ovaries were collected from August to October which comprised of stages III+ to VIIb. It may be seen from Table X and Fig. 1 that two distinct modes of maturing ova manifest themselves even at stage III+, the more advanced mode is at 25-26 m.d. and the less advanced one at 15-16 m.d. A stage IV

TABLE IX

Comparison of diameter frequencies based on 1000 and 300 ova drawn from 6 different ovaries

Ova diameter in m.d.	1-8-61 (161 mm.)		1-8-61 (156 mm.)		14-8-61 (168 mm.)		16-8-61 (155 mm.)		14-8-61 (163 mm.)		14-8-61 (160 mm.)	
	For 1000	For 300	For 1000	For 300	For 1000	For 300	For 1000	For 300	For 1000	For 300	For 1000	For 300
5-6 .	90	30	108	36	114	36	176	48	168	52	318	120
7-8 .	74	22	79	17	77	29	88	23	203	60	212	53
9-10 .	76	28	82	29	66	19	46	13	127	38	166	44
11-12 .	42	9	49	12	46	15	28	8	80	29	99	28
13-14 .	35	8	37	10	39	12	18	8	35	11	54	14
15-16 .	58	13	57	19	39	6	26	4	46	11	52	15
17-18 .	19	4	25	8	24	3	15	4	56	19	36	9
19-20 .	61	18	40	12	41	11	13	3	70	24	39	10
21-22 .	41	16	37	13	25	8	15	2	38	10	12*	3*
23-24 .	25	3	19	11	34	9	28	13	70	19	11*	4*
25-26 .	25	8	39	13	63	22	53	16	61	17	1*	0*
27-28 .	25	9	45	10	33	12	65	71	31	8	..	..

29-30 .	62	22	105	26	28	4	79	24	15	2	..	..
31-32 .	65	23	91	25	25	5	41	15	..	..	..	..
33-34 .	65	16	74	23	60	21	51	20	..	..	..	..
35-36 .	100	33	69	19	88	25	103	31	..	..	..	..
37-38 .	68	20	32	9	84	22	88	30	..	..	..	..
39-40 .	51	11	10*	6*	85	27	48	15	..	..	..	..
41-42 .	15*	6*	2*	2*	17	9	14*	4*	..	..	..	..
43-44 .	2*	1*	..	..	7*	3*	3*	1*	..	..	..	..
45-46 .	1*	0*	..	..	4*	2*	1*	1*	..	..	..	..
47-48 .	..	..	..	..	1*	0*	1*	0*	..	..	..	..
D.F. .		18		17		19		18		12		8
Chi-Square		18.247		24.241		22.811		15.872		6.351		13.973
P .		0.50		0.10		0.20		0.50		0.80		0.05
Stage of maturity		IV FB		IV		IV+		IV+		VIIa		VIIb

*Pooled together because of low frequencies.

D.F.=Degree of freedom; P=Probability; F.B.=Follicular breakdown.

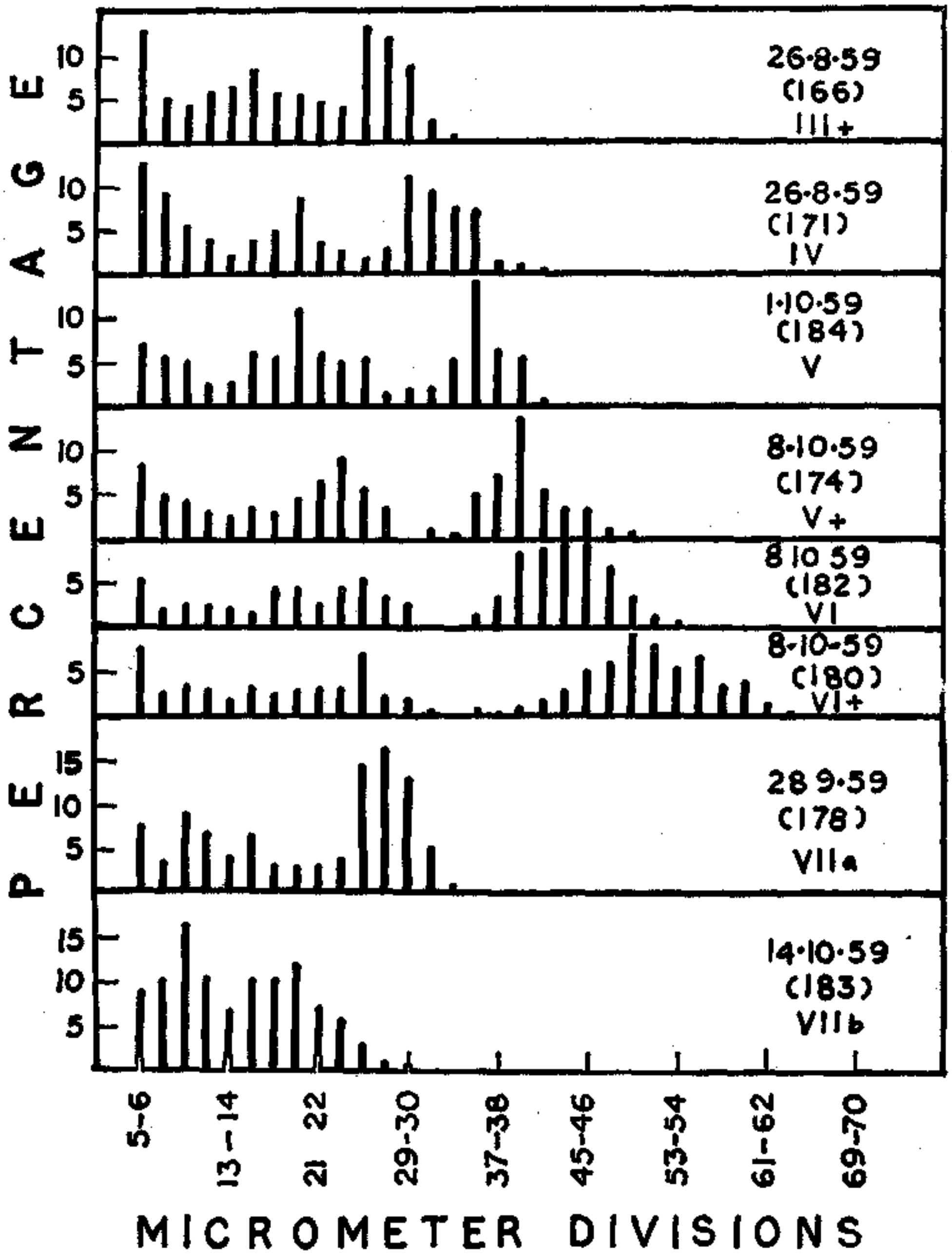

FIG. 1. Ova diameter frequency for 1959. (The length of fish in mm. is given in parentheses)

ovary shows the modes shifting to 29-30 and 19-20 m.d. respectively. In stage V, there is further shifting in both the modes indicating that growth takes place in both sets of ova. Two ovaries belonging to stage VI show that while the more advanced group has progressed from 39-40 to 49-50 m.d., the less advanced group stops growth at 25-26 m.d. so much so, the last mode clearly delimits itself away from the preceding mode. The maximum diameter of ripe ova measured is 68 m.d. (1.2376 mm). This particular ovary with the last mode at 49-50 m.d. *i.e.,* 0.8918 to 0.9100 mm may be considered as the ripest ovary of the entire observation period, in which the spawning would have been imminent. The stage VIIa which represents partially spawned condition shows the last mode at 27-28 m.d. Considering the fact that the less advanced mode in Stage VI is at 25-26 m.d., it can be safely assumed that this batch of ova has not been rushed through and spawned out, but left behind in the ovary. The fact that in this stage there are other modal groups at 9-10 and 15-16 m.d. which are not evident in earlier stages appears to indicate that the fish may go through another act of spawning. However, the possibility or otherwise of subsequent spawning will be discussed later with other available evidences. The completely spent ovaries in Stage VIIb in October also show two modes being left behind, one at 19-20 and the other at 9-10 m.d. In general, it is also seen that as the season progresses and maturity advances, number of ova less than 10 m.d. becomes diminished, indicating that for the advancement of maturity, ova are drawn from the immature stock.

1960

The observation period extended from May to November and the data are presented in Table XI and Fig. 2 which include all the stages from IIa to VIIb except V & VI. It is seen that the first signs of modal formation become evident at stage III when there is only one maturing mode at 21-22 m.d. Before the ovary advances to Stage IV, perhaps, the secondary mode also registers its appearance, for while the major mode has shifted to 25-26 m.d., a minor one appears at 13-14 m.d. All these stages have been obtained in May and in June, all the ovaries are in Stage IV with the more advanced mode at 29-30 m.d. and the less advanced one at 15-16 m.d. The same condition is obtained in early August also but in the second half of August ovaries belonging to both stages, IV+ and VIIa, are obtained. During this year not even a single stage V ovary could be obtained and the most mature ovary available is not beyond stage IV+ wherein the principal mode has shifted to 33-34 m.d. while the secondary one is stationary at 15-16 m.d. In the partially spawned condition also there are two modal groups left behind with the larger sized ova anywhere between 23 and 30 m.d. and the small sized ova between 13 and 16 m.d. except during the end of August, when a stage VIIa ovary has only one mode, a group of larger opaque ova. These partially spent ovaries are obtained along with stage IV+ in the same samples. In September, there are no maturing or mature ovaries and the materials obtained are in completely spent condition, sometimes with remnants of unspawned ova forming a mode at 15-16 m.d. and sometimes with no modal

TABLE X

Percentage frequencies of ova diameter in micrometer units for 1959 showing the position of modes(*)

Diameter	Date, length of fish in mm. and stage of maturity								
	26-8-59 166 III+	26-8-59 171 IV	28-9-59 178 VIIa	1-10-59 184 V	8-10-59 174 V	8-10-59 182 VI	8-10-59 180 VI	14-10-59 183 VIIb	14-10-59 168 VIIb
5-6 . .	13.2	12.5	7.5	7.2	8.6	5.5	7.7	9.2	15.1
7-8 . .	5.0	9.1	3.5	5.5	5.0	2.1	2.7	10.0	5.5
9-10 .	4.5	5.6	8.8*	5.2	4.3	2.8	3.4	16.6*	17.9*
11-12 . .	6.2	4.0	6.9	2.7	3.0	2.6	3.0	10.7	10.1
13-14 . .	6.6	2.7	3.8	2.6	2.4	1.8	1.4	5.8	6.8
15-16 . .	8.3*	4.2	6.6*	6.2	3.7	1.7	3.1	10.6	7.3
17-18 . .	5.4	5.2	3.0	5.5	3.1	4.3	2.4	10.0	4.3
19-20 . .	5.7	9.1*	2.9	10.9*	4.3	4.6	3.0	11.8*	10.0*
21-22 . .	4.6	3.3	3.0	5.9	6.7	2.7	2.8	6.9	6.4
23-24 . .	3.9	2.5	4.2	4.9	8.9*	4.6	2.8	5.3	6.0
25-26 . .	13.5*	1.8	14.7	5.5	5.7	5.7	7.0*	2.3	8.2
27-28 . .	12.0	2.7	16.5*	1.6	3.0	3.7	1.9	0.6	1.7
29-30 . .	8.3	10.8*	13.1	2.2	0.2	2.6	1.9	0.2	0.7
31-32 . .	2.3	9.7	4.5	2.1	0.9	0.4	0.2	..	..

33-34 . .	0.5	7.5	0.8	5.1	0.7	0.3	0.2	..	..
35-36 . .	..	7.2	0.2	14.2*	4.8	1.7	0.6	..	..
37-38 . .	..	1.1	..	6.7	7.3	3.3	0.1	..	..
39-40 . .	..	0.9	..	5.5	13.4*	8.7	0.9	..	..
41-42 . .	..	..	..	0.3	5.3	9.1	1.5	..	..
43-44 . .	..	..	..	0.2	3.5	10.0*	2.4	..	..
45-46 . .	..	0.1	..	..	3.7	10.0	4.8	..	..
47-48 . .	..	..	..	..	1.2	7.0	5.8	..	..
49-50 . .	..	..	..	..	0.3	3.5	10.1*	..	..
51-52 . .	..	..	..	..	..	0.9	8.2	..	..
53-54 . .	..	..	..	..	..	0.4	5.5	..	..
55-56 . .	..	..	..	..	..	..	6.9	..	..
57-58 . .	..	..	..	..	..	..	3.4	..	..
59-60 . .	..	..	..	..	..	..	4.1	..	..
61-62 . .	..	..	..	..	..	..	1.2	..	..
63-64 . .	..	..	..	..	..	..	0.6	..	..
65-66 . .	..	..	..	..	..	..	0.3	..	..
67-68 . .	..	..	..	..	..	..	0.1	..	..

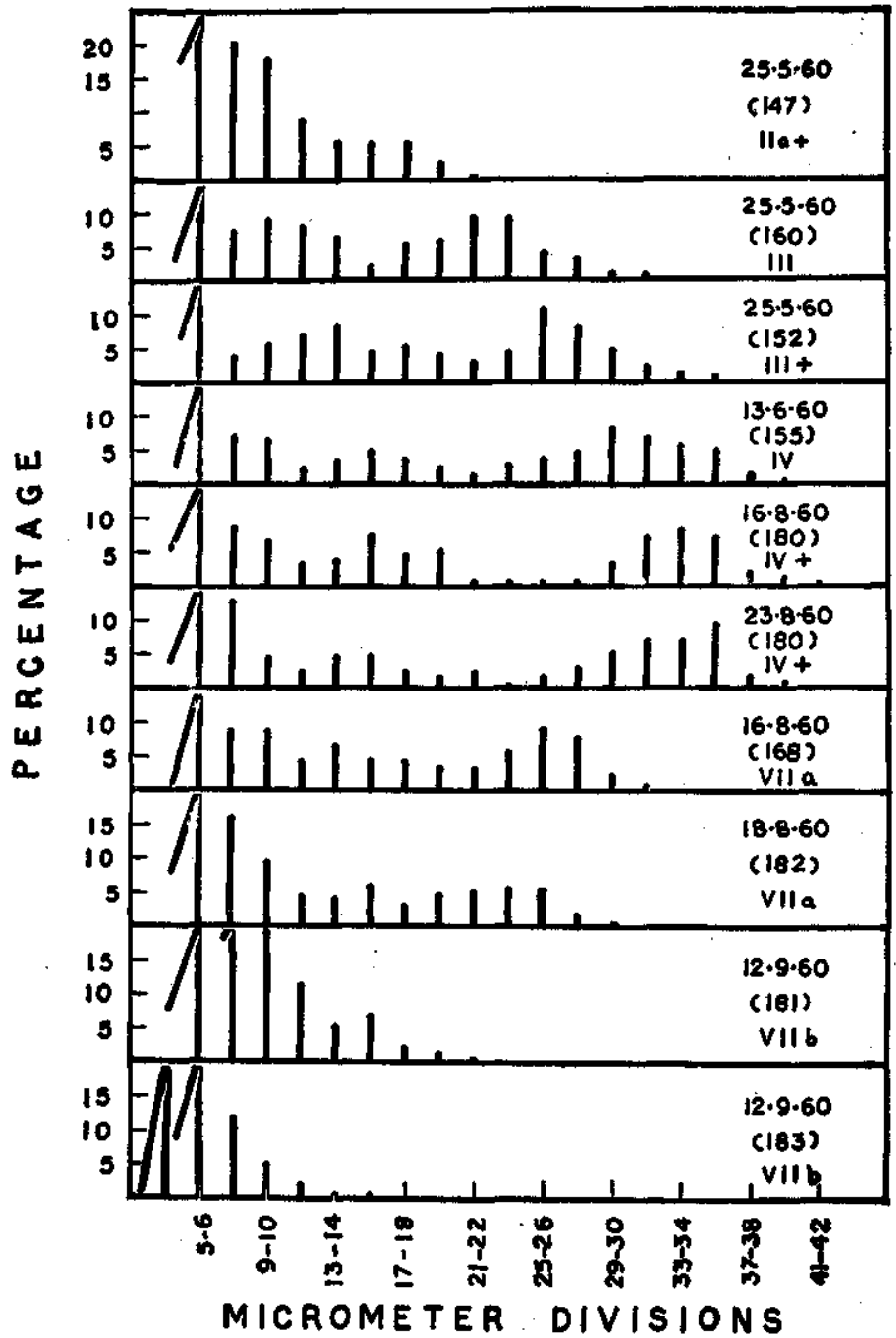

FIG. 2. Ova diameter frequency for 1960

formation. The ovaries in October and November represent only the spent-resting condition when no ovum exceeded 8 m.d. with remnants of spawning left behind as small brownish masses.

1961

By far, largest number of ovaries is examined during this year when the collections covered a period from June to September comprising of all stages from IIb+ to VIIb except stage VI. The data are presented in Table XII and Fig. 3. In June, stages II to IV are obtained. Unlike stage IIa which is virgin maturing and wherein the maturing ova do not form a distinct mode by themselves, stage IIb represents spent-resting phase and at the approach of spawning season, the ovary recovers and the maturing ova quickly form a mode as seen in stage IIb+ on 3-6-61. In this stage the maturing mode is at 17-18 m.d. and in stage III also, there is a single maturing mode now at 21-22 m.d. This mode progresses to 25-26 m.d. in a little advanced condition when the second mode becomes evident at 13-14 m.d. In stage IV, the principal mode stands at 29-30 m.d. followed by the secondary mode at 15-16 m.d. These changes and progression of modal groups are exactly similar to those recorded for 1960. In August, the fish have advanced to stage V with the more advanced mode at 35-36 m.d. and the other mode at 19-20 m.d. Largest number of ovaries has been examined in August when ovaries presented varying appearances and belonged to stage IV+, V, VIIa and VIIb. There are also instances of follicular breakdown in the advanced ovaries of stage V (Antony Raja, MS. z). In these ovaries registering follicular breakdown, the modal positions are not altered but there is a significant reduction in the number of ova belonging to the more advanced mode. On 14-8-1961, there are instances of both partially spawned and completely spent phases of ovaries. As can be seen from Table XII or Fig. 3, the three partially spent fish have the unspent ova forming modes at different levels, at 25-26, 23-24 and 19-20 m.d. respectively whereas in stage VIIb, there is no mode evident except in the immature stock with remnants of spawning in the form of a few disintegrating ova up to 25-26 m.d. In late August also, the modal diameter of ova left behind in stage VIIa vary from 29-30 to 23-24 m.d. There are also instances of late maturing fish during the end of August when the modal diameters are 33-36 m.d. and 15-16 m.d. In September, only fully spent fish are obtained showing the progressive diminution of modal size.

1962

The selected data for 1962 are presented in Table XIII and Fig. 4. Unlike the previous years where it was not so strikingly evident, the presence of two distinct size groups of spawners representing two successive generations was clearly recognised during this year. Since the ripening of ova and modal formation presented certain differences between these two groups, the virgin spawners

TABLE XI

Percentage frequencies of ova diameter in micrometer units for 1960 showing the position of modes (*)

Diameter	Date, length of fish in mm. and stage of maturity							
	20-5-60 148 IIa	25-5-60 147 IIa+	25-5-60 160 III	25-5-60 152 III+	13-6-60 155 IV	2-8-60 172 IV	16-8-60 180 IV+	16-8-60 168 VIIa
1-2	2.0	..	..	..	..	..	..	..
3-4	18.0	..	..	..	..	..	..	..
5-6	42.3*	32.0	26.3	23.3	27.3	27.3	24.0	29.3
7-8	18.0	20.7	7.7	4.0	7.0	9.3	8.7	9.0
9-10	10.3	18.7	9.3	6.0	6.7	6.3	7.0	9.0
11-12	7.7	9.0	8.0	7.3	2.7	2.3	3.7	4.0
13-14	1.7	5.3	6.3	8.7*	3.3	3.0	4.0	6.3*
15-16	..	5.7	2.0	5.0	5.0*	8.7*	8.0*	4.3
17-18	..	5.7	5.7	5.3	3.7	4.4	5.0	4.3
19-20	..	2.3	6.0	4.0	2.7	2.0	5.3	3.7
21-22	..	0.7	9.7*	3.0	1.7	1.3	1.0	3.0
23-24	..	..	9.3	4.7	3.0	2.0	1.0	5.7

25-26	..	..	4.0	11.0*	4.0	2.3	1.0	9.7*
27-28	..	..	3.3	8.7	4.3	4.3	1.0	8.0
29-30	..	..	1.7	5.0	8.7*	8.7*	3.7	2.7
31-32	..	..	0.7	2.3	7.0	8.4	7.3	1.0
33-34	..	..	..	1.0	6.0	5.0	8.7*	..
35-36	..	..	..	0.7	5.0	3.3	7.3	..
37-38	..	..	..	..	1.6	0.4	2.0	..
39-40	..	..	..	..	0.3	1.0	1.0	..
41-42	..	..	..	..	..	..	3.0	..

TABLE XI—*Contd.*

Percentage frequencies of ova diameter in micrometer units for 1960 showing the position of modes (*)

Diameter	Date, length of fish in mm. and stage of maturity								
	18-8-60 176 IV+	18-8-60 182 VIIa	23-8-60 180 IV+	23-8-60 172 VIIa	23-8-60 177 VIIa	12-9-60 181 VIIb	12-9-60 183 VIIb	18-10-60 181 IIb	16-11-60 169 IIb
1-2 . . .	..	..	..	..	..	..	..	30.0	18.3
3-4 . . .	..	..	..	..	..	..	47.3*	62.0*	58.7*
5-6 . . .	23.3	32.7	26.0	30.0	36.3	31.0	31.0	8.0	21.0
7-8 . . .	8.7	16.0	12.3	15.7	12.7	21.3	11.7	..	2.0
9-10 . . .	5.3	9.3	4.3	8.0	6.3	19.7	5.3	..	..
11-12 . . .	4.0	4.7	2.7	5.0	4.0	11.3	2.7	..	..
13-14 . . .	4.0	4.7	4.3	3.7	2.7	5.3	1.0	..	..
15-16 . . .	7.3*	6.0*	5.0*	6.0*	3.0	7.0*	1.0	..	..
17-18 . . .	5.3	3.0	2.7	4.7	3.0	2.7	..	..	..
19-20 . . .	3.0	5.0	2.0	1.7	1.7	1.3	..	..	..
21-22 . . .	1.3	5.3	2.7	1.3	1.7	0.4	..	..	..
23-24 . . .	1.0	5.7*	0.4	1.3	4.3	..	..	..	..

25-26	1.0	5.7	2.0	2.3	5.0	..	..	..	..
27-28	2.3	1.7	3.0	6.7	7.7*				
29-30	5.7	0.2	5.3	8.3*	6.7	..	..	..	..
31-32	8.3	..	7.3	4.0	3.7	..	..	..	..
33-34	8.7*	..	7.0	1.3	1.2	..	..	..	..
35-36	7.0	..	10.0*	..	..	..	..	..	..
37-38	3.3	..	2.0	..	..	..	..	..	..
39-40	0.5	..	1.0	..	..	..	..	..	..
41-42	..	..	..	..	..	..	..	..	..

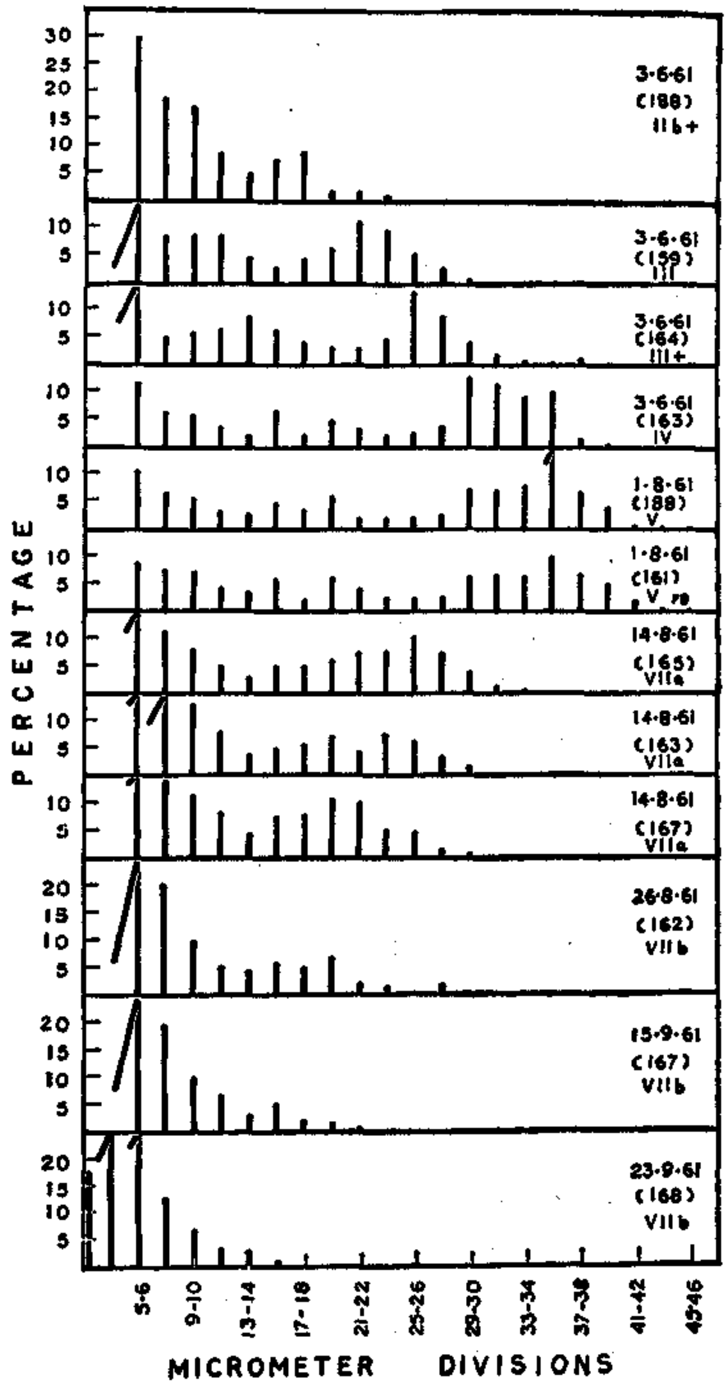

FIG. 3.—Ova diameter frequency for 1961.

and recovering spawners are described separately. The materials relate to May-August period and since the nature of completely spent and spent-resting ovaries has already been thoroughly examined in the previous years, concentration has been laid only on ovaries up to partially spawned condition in stage VIIa. In the virgin spawners class, there is only one maturing mode in May which

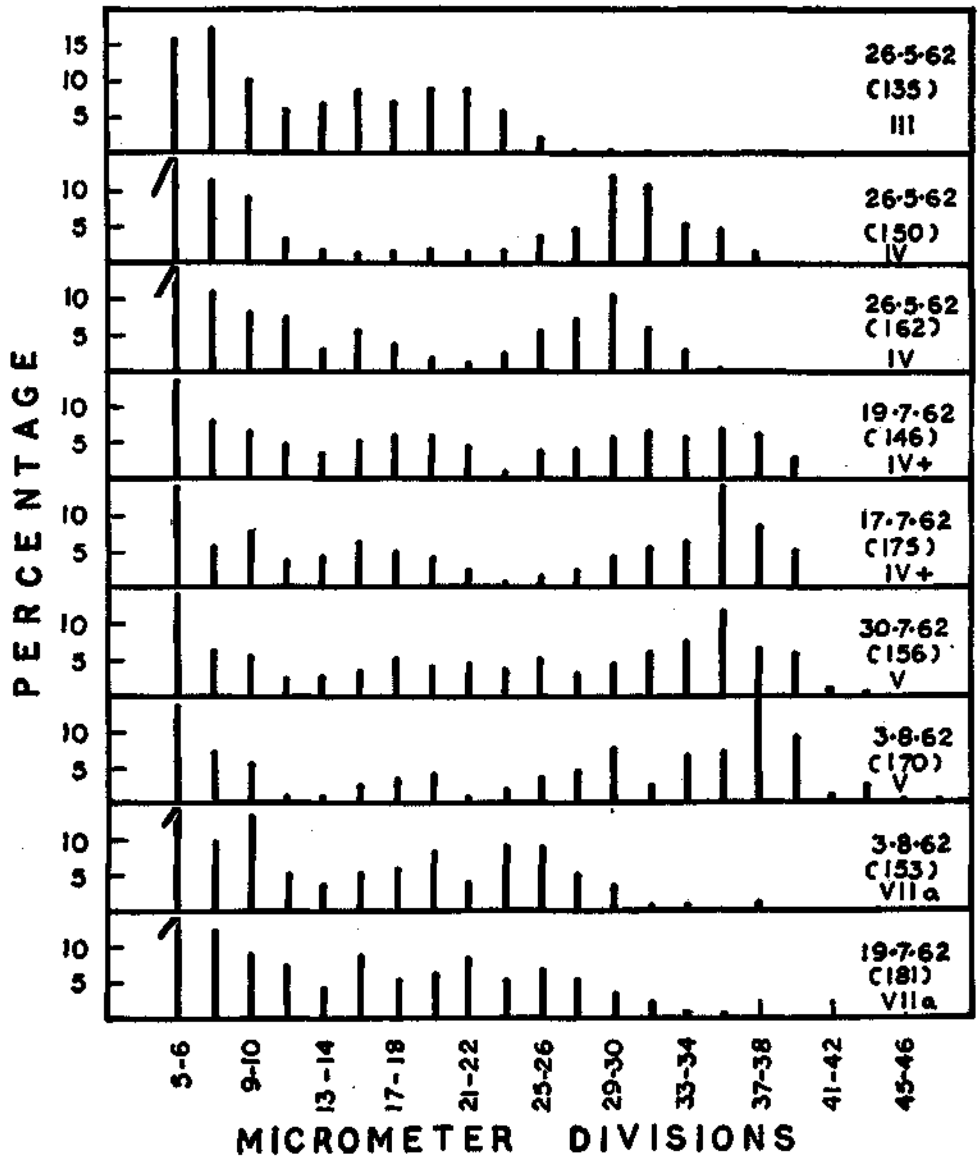

FIG. 4. Ova diameter frequency for 1962.

TABLE XII

Percentage frequencies of ova diameter in micrometer units for 1961 *showing the position of modes* (*)
(FB=Follicular breakdown)

Diameter	Date, length of fish in mm. and stage of maturity									
	3-6-61 188 IIb+	3-6-61 159 III	3-6-61 164 III+	3-6-61 183 IV	1-8-61 188 V	1-8-61 161 VFB	14-8-61 168 V	14-8-61 165 VIIa	14-8-61 163 VIIa	14-8-61 167 VIIa
1-2 .	..	..	..	..	..	..	..	..	..	..
3-4 .	..	..	..	..	..	..	..	..	..	..
5-6 .	30.0	27.3	22.3	11.8	10.3	9.0	11.4	18.0	16.8	16.2
7-8 .	18.7	8.3	5.0	6.3	6.4	7.4	7.7	11.4	20.3	14.3
9-10 .	17.3	8.7	5.7	6.0	5.5	7.6	6.6	8.5	12.7	11.6
11-12 .	8.7	8.7	6.7	3.4	3.3	4.2	4.6	5.6	8.0	7.8
13-14 .	4.7	4.3	9.0*	2.1	2.7	3.5	3.9	3.1	3.5	4.0
15-16 .	7.3	2.7	6.3	6.5*	4.5*	5.8	3.9	5.1	4.6	7.2
17-18 .	8.7*	4.7	4.3	2.0	3.3	1.9	2.4	5.0	5.6	7.5
19-20 .	1.7	6.3	3.3	4.7	5.7*	6.1*	4.1	5.8	7.0	10.8*
21-22 .	1.7	11.3*	3.0	3.3	1.8	4.1	2.5	7.6	3.8	9.8
23-24 .	1.2	9.7	4.3	1.9	2.1	2.5	3.4	7.4	7.0*	4.5

25-26 .	..	5.0	13.3*	2.6	1.8	2.5	6.3*	10.2*	6.1	4.6
27-28 .	..	2.7	9.0	3.5	2.2	2.5	3.3	7.0	3.1	1.3
29-30 .	..	0.3	4.0	12.9*	7.1	6.2	2.8	4.1	1.5	0.4
31-32 .	..	..	2.0	11.7	7.0	6.5	2.5	1.0	..	..
33-34 .	..	..	0.7	9.3	7.7	6.5	6.0	0.2	..	..
35-36 .	..	..	..	10.2	17.3*	10.0*	8.8*	..	..	..
37-38 .	..	..	1.1	1.5	6.5	6.8	8.4	..	..	..
39-40 .	..	..	..	0.3	3.8	5.1	8.5	..	..	..
41-42 .	..	..	..	..	0.5	1.5	1.7	..	..	..
43-44 .	..	..	..	..	0.3	0.2	0.7	..	..	..
45-46 .	..	..	..	..	0.2	0.1	0.4	..	..	..
47-48 .	..	..	..	..	..	..	0.1	..	..	..

TABLE XII—(*Contd.*)

Percentage frequencies of ova diameter in micrometer units for 1961 *showing the position of modes* (*)
(FB=Follicular breakdown)

Diameter	Date, length of fish in mm. and stage of maturity									
	14-8-61 160 VIIb	16-8-61 187 V	16-8-61 161 IV+	18-8-61 167 VIIa	23-8-61 188 VIIa	23-8-61 172 IV+	26-8-61 155 V	26-8-61 162 VIIb	15-9-61 167 VIIb	23-9-61 168 VIIb
1-2 .	..	..	..	..	..	..	..	..	..	15.7
3-4 .	..	..	..	..	..	..	..	..	..	30.0*
5-6 .	31.8	32.7	26.7	26.7	27.3	24.7	28.3	38.7	43.7	27.7
7-8 .	21.2	7.0	9.0	15.0	12.3	7.7	11.3	19.7	28.7	12.3
9-10 .	16.6	6.3	3.0	8.0	11.0	6.0	5.0	9.7	10.0	7.0
11-12 .	9.9	2.7	3.7	4.7	7.7	5.0	4.3	5.3	6.7	3.3
13-14 .	5.4	0.7	3.7	4.0	4.3	3.3	4.0	4.3	2.7	3.0
15-16 .	5.2	2.3	3.0	4.0	6.0	8.7*	7.0*	5.7	4.7*	1.0
17-18 .	3.6	1.0	1.3	3.0	7.0	5.3	2.7	5.0	1.7	..
19-20 .	3.9	2.0	2.0	2.3	4.7	3.3	3.0	6.7*	1.3	..
21-22 .	1.2	1.0	1.3	3.0	4.3	1.7	2.7	2.0	0.5	..
23-24 .	1.1	2.3	2.7	3.3	6.0*	1.3	1.3	1.3	..	..

25-26 .	0.1	2.7	2.0	5.0	5.7	1.7	2.0	..	..	..
27-28 .	..	1.7	2.7	5.3	3.3	1.7	2.7	1.6	..	..
29-30 .	..	4.3*	7.3*	7.7*	0.4	7.7	5.0	..	..	..
31-32 .	..	3.0	3.7	4.7	..	6.3	5.7	..	..	..
33-34 .	..	3.3	5.7	1.0	..	9.0*	5.0	..	..	..
35-36 .	..	10.3*	7.3*	1.7	..	5.3	6.7*	..	..	..
37-38 .	..	4.0	6.3	0.6	..	0.7	2.0	..	..	..
39-40 .	..	8.3	6.0	..	..	0.6	0.7	..	..	..
41-42 .	..	2.0	1.6	..	..	..	..	..	..	..
43-44 .	..	1.3	1.0	..	..	..	..	..	..	..
45-46 .	..	0.7	..	..	..	..	0.6	..	..	..
47-48 .	..	0.4	..	..	..	..	..	..	..	..

progresses from 21-22 m.d. in stage III to 29-30 m.d. in stage IV. In July, while the principal mode has shifted to 35-36 m.d. in stages IV+ and V, a secondary mode appears between 17-20 m.d. But unlike the previous years, this second mode is not very distinctly marked out. Among the partially spent ovaries in this year class, the unspent ova form two modes at 27-28 and 19-20 m.d. in July whereas in early August there is a mode at 23-24 m.d. and the other mode is far behind at 9-10 m.d. At the end of August the latter mode is not evident whereas the only mode is at 29-30 m.d. Regarding the recovering spawners group, unlike virgin spawners, even as early as May two modes manifest in stage IV, one at 15-18 m.d. and the other at 29-30 m.d. In middle July, while the less advanced group appears to remain static, the other group has progressed to 35-36 m.d. in stage IV+. By the end of July, in stage V, the two modes appear at 19-20 and 35-36 m.d. Surprisingly in early August (3-8-1962) stage V ovaries show three modes at the levels of 19-20, 29-30 and 37-38 m.d., that is, a mode in between the two modes already registered at the end of July in stage V. However, considering the picture of other ovaries collected on the same day which have undergone follicular breakdown and wherein only two modal groups are present at 17-18 and 29-30 m.d., it is assumed that the larger ova at 37-38 m.d. have undergone atresia. In the other ovaries collected during August and belonging to stage IV, wherein no incidence of follicular breakdown is noticed, there is a typical bimodal appearance among the maturing ova at 29-30 and 15-18 m.d. In this recovering spawners group, stage VIIa is seen only in July when the unspawned ova, although formed two modes at 15-16 and 21-22 m.d., may be treated as one group in view of the narrow interval.

1963

The related data are presented in Table XIV and Fig. 5. This year also attention has been focussed mainly on maturing ovaries in stage IV due to absence of advanced stages like V in the collections made during June to September. This year also there have been two successive generations entering the spawning season which are treated separately in the following account. The virgin spawners in stage IV and IV+ in June carry two groups of maturing ova, one progressing from 15-16 to 21-22 m.d. and the other from 29-30 to 35-36 m.d. In July also the bimodal frequency is evident at 15-16 and 33-34 m.d. In August, while a few ovaries in stage IV present similar appearances, those that have spawned partially have the remnants of ova forming a mode at 25-26 m.d. Even till late in September maturing fish have been obtained unlike the previous years and the bimodal nature of diameter frequencies is typical of stage IV with modes at 15-16 and 29-30 m.d. In the case of recovering spawners, the reverse of the condition obtained during 1962 is noticed, for, only one modal group develops at 29-30 m.d. in stage IV ovaries. It may be recalled that these belong

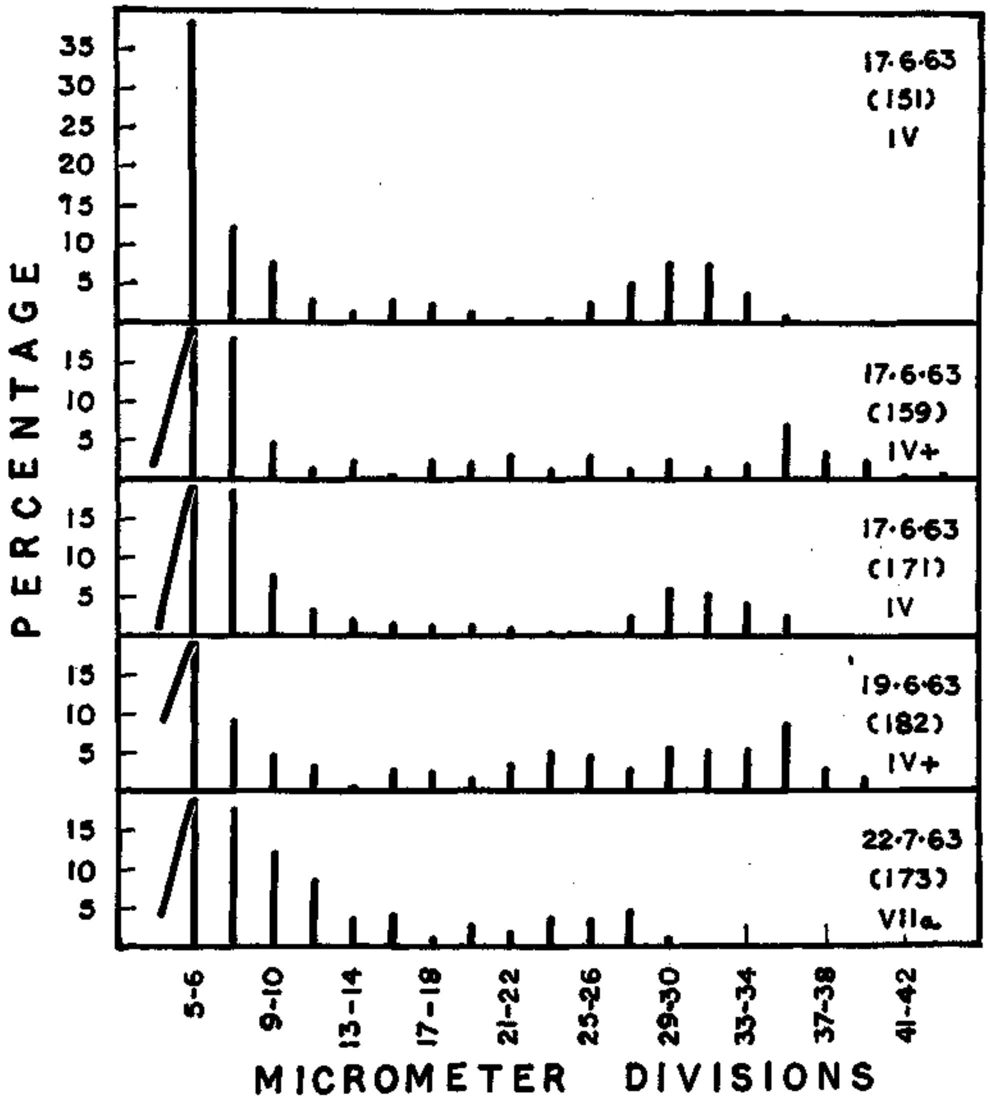

FIG. 5. Ova diameter frequency for 1963.

to the stock which were virgin spawners during the previous season when they carried only one clear mode at 31-32 or 33-34 m.d. which picture is obtained in September of this year also. In partially spent ovaries, the left-over ova appear to form a mode at 27-28 m.d. but it is not very distinct as in other years. Instances of follicular breakdown have been noticed in both the groups throughout June to September.

TABLE XIII

Percentage frequencies of ova diameter in micrometer units for 1962 showing the position of modes (*)

(VS=Virgin spawners; SR=Recovering spawners)

(FB=Follicular breakdown)

Diameter	Date, length of fish in mm. and stage of maturity								
	26-5-62 135(VS) III	26-5-62 150(VS) IV	26-5-62 162(SR) IV	26-5-62 170(SR) IV	17-7-62 175(SR) IV+	17-7-62 152(VS) IV	19-7-62 181(SR) VIIa	19-7-62 146(VS) IV+	30-7-62 174(SR) V
5-6 . . .	16.0	20.3	19.7	20.0	14.0	12.0	18.0	14.0	12.0
7-8 . . .	17.7	16.7	16.7	14.0	5.7	9.0	12.7	8.3	5.3
9-10 . . .	10.3	9.3	8.0	8.0	8.0	8.7	8.7	6.3	6.0
11-12 . . .	6.0	3.3	7.3	4.3	3.7	8.0	7.0	5.0	5.3
13-14 . . .	7.0	1.7	3.0	1.7	4.3	7.7	3.7	3.7	4.3
15-16 . . .	9.0*	1.3	5.3*	3.0	6.0*	8.0	8.3*	5.3	5.7
17-18 . . .	7.0	1.3	3.7	4.0*	4.7	7.3	5.0	6.0	5.7
19-20 . . .	8.7	1.3	1.7	2.3	4.0	3.0	5.7	6.0*	8.3*
21-22 . . .	9.0*	1.7	1.0	2.3	2.3	4.7	8.3*	4.3	4.3
23-24 . . .	5.7	1.3	2.3	2.7	0.7	4.0	5.0	0.7	0.7
25-26 . . .	2.3	3.3	5.3	4.3	1.3	12.0*	6.3	3.7	1.3

27-28 . . .	..	4.3	6.7	4.3	2.3	8.7	5.0	3.7	2.0
29-30 . . .	0.7	12.0*	10.7*	11.0*	4.3	4.7	3.0	5.7	1.0
31-32 . . .	..	10.7	5.3	10.0	5.3	2.2	2.0	6.3	3.3
33-34 . . .	0.6	5.3	2.7	5.3	6.0	..	0.7	5.3	6.7
35-36 . . .	..	4.7	0.6	2.3	14.3*	..	0.6	7.0*	12.7
37-38 . . .	..	1.5	..	0.5	8.0	..	..	6.0	9.7
39-40 . . .	..	..	..	..	5.1	..	..	2.7	4.0
41-42 . . .	..	..	..	..	..	..	..	..	1.3
43-44 . . .	..	..	..	..	..	..	..	..	..
45-46 . . .	..	..	..	..	..	..	..	..	0.4
47-48 . . .	..	..	..	..	..	..	..	..	..

TABLE XIII—(*Contd.*)

Percentage frequencies of ova diameter in micrometer units for 1962 showing the position of modes (*)

(VS=Virgin spawners; SR=Recovering spawners)

(FB=Follicular breakdown)

Diameter	Date, length of fish in mm and stage of maturity								
	30-7-62 156(VS) V	30-7-62 158(VS) VIIa	3-8-62 170(SR) V	3-8-62 175(SR) IV FB	3-8-62 153(VS) VIIa	7-8-62 171(SR) IV†	7-8-62 155(VS) IV+	10-8-62 180(SR) IV+	30-8-62 168(VS) VII
5-6 . . .	14.0	17.7	14.0	14.0	17.3	14.0	12.0	12.0	14.0
7-8 . . .	6.3	9.7	7.3	9.7	9.3	11.0	15.0*	4.7	9.7
9-10 . . .	5.7	4.7	5.7	7.0	13.7*	8.3	13.3	6.0	8.3
11-12 . . .	2.3	4.0	1.0	4.3	5.3	6.0	7.3	6.7	4.3
13-14 . . .	2.7	3.7	1.0	2.3	3.7	2.7	6.0	3.3	5.7
15-16 . . .	3.3	6.3	3.3	3.0	5.0	4.0	5.0	4.7*	6.3
17-18 . . .	5.0*	3.7	3.7	6.0*	6.0	5.0	2.7	3.0	4.7
19-20 . . .	3.7	9.7*	4.0*	3.3	8.3*	8.3*	3.7	3.0	1.7
21-22 . . .	4.3	5.3	0.3	3.0	3.7	6.3	1.3	3.3	1.7
23-24 . . .	3.3	5.7	1.7	3.7	8.7*	1.3	1.7	3.0	1.7
25-26 . . .	4.7	7.0	3.3	2.0	8.3	3.7	1.7	3.0	8.0

27-28 . . .	3.0	9.7*	4.0	6.7	5.0	1.7	2.3	2.7	11.3
29-30 . . .	4.0	9.3	7.7*	11.3*	3.3	3.0	4.0	6.3	11.7*
31-32 . . .	6.0	1.7	2.0	5.3	0.7	4.7	6.3	9.3	7.7
33-34 . . .	7.0	..	7.3	6.7	0.7	7.0*	9.0*	11.0*	2.7
35-36 . . .	11.7*	1.0	7.0	4.3	..	6.7	6.3	10.3	0.5
37-38 . . .	6.0	0.6	14.3*	6.0	1.0	4.0	2.0	6.3	..
39-40 . . .	5.7	0.2	9.0	1.4	..	2.3	..	1.4	..
41-42 . . .	0.7	..	0.7	..	..	..	0.4	..	..
43-44 . . .	0.6	..	2.7	..	..	..	..	..	..
45-46 . . .	..	..	0.3	..	..	..	..	..	..
47-48 . . .	..	..	0.7	..	..	..	..	..	..

TABLE XIV

Percentage frequencies of ova diameter in micrometer units for 1963 *showing the position of modes* (*)

(VS=Virgin spawners; SR=Recovering spawners; FB=Follicular breakdown)

Diameter	Date, length of fish in mm. and stage of maturity						
	17-6-63 151 (VS) IV	17-6-63 159 (VS) IV+	17-6-63 171 (SR) IV	17-6-63 181 (SR) IV	19-6-63 182 (SR) IV+	19-6-63 181 (SR) IV FB	15-7-63 161 (VS) IV+
5-6	38.3	38.3	42.3	43.7	31.0	43.7	29.3
7-8	12.7	18.0	18.3	9.7	9.0	10.0	7.3
9-10	7.7	5.0	7.3	5.7	4.3	5.3	5.7
11-12	3.0	1.7	3.3	4.3	3.7	4.3	7.3
13-14	1.7	2.3	2.0	5.3	0.7	5.3	2.0
15-16	3.0*	0.7	1.7	3.0	3.0	3.0	4.7*
17-18	2.3	2.7	1.3	1.7	2.7	1.7	3.7
19-20	1.7	2.3	1.3	1.0	1.7	1.0	4.0
21-22	0.7	3.3*	1.0	..	3.3	2.7	2.3
23-24	0.7	1.3	0.3	2.7	5.0	3.7	1.7
25-26	2.7	3.0	0.7	3.7	4.3	3.0	1.7
27-28	5.3	1.3	2.3	3.0	3.0	8.0*	1.0

29-30	7.7*	2.7	6.0*	7.7*	5.3	5.0	5.0
31-32	7.3	1.7	5.7	5.3	5.0	2.3	8.3
33-34	4.2	2.0	4.0	2.2	5.0	1.0	10.0*
35-36	1.0	7.0*	2.5	1.0	8.7*	..	4.3
37-38	..	3.3	..	..	2.7	..	1.7
39-40	..	2.3	..	..	1.6	..	..
41-42	..	0.4	..	..	..	..	..
43-44	..	0.7	..	..	..	..	..

TABLE XIV—(*Contd.*)

Percentage frequencies of ova diameter in micrometer units for 1963 showing the position of modes (*)

(VS = Virgin spawners; SR = Recovering spawners;
FB = Follicular breakdown)

Diameter	Date, length of fish in mm and stage of maturity							
	15-7-63 173 SR IV	22-7-63 175 SR IV+	22-7-63 173 SR VIIa	6-8-63 159 VS VIIa	6-8-63 178 SR IV	30-9-63 165 VS IV	30-9-63 175 SR IV	30-9-63 180 SR IV+ FB
5-6	20.3	25.0	36.0	32.0	26.0	30.0	31.3	36.0
7-8	11.7	14.0	17.3	16.0	12.0	8.7	11.0	16.3
9-10	9.0	13.3	12.0	14.0	10.3	5.7	9.7	6.3
11-12	5.3	4.7	8.3	3.7	8.0	5.0	3.7	4.0
13-14	4.0	4.3	3.3	2.3	3.7	2.3	2.7	4.0
15-16	4.7	5.3	4.0	6.7*	2.0	4.0*	3.3	1.3
17-18	4.3	4.0	1.0	3.7	3.7	2.7	2.3	2.0
19-20	4.0	2.3	2.7	2.0	3.0	2.0	3.3	3.0
21-22	2.0	1.0	1.7	2.0	5.0	1.7	1.7	2.0
23-24	0.3	1.0	3.3	5.3	4.3	3.0	3.3	1.0
25-26	1.3	2.0	3.3	6.7*	13.0*	5.3	4.0	2.0

27-28	2.3	1.0	4.3*	4.0	7.3	9.7	11.0*	1.7
29-30	3.7	2.3	1.1	1.6	0.7	13.7*	11.0	3.3
31-32	9.3*	6.7	..	..	1.0	5.0	1.3	7.3*
33-34	6.0	7.0*	..	..	..	1.2	0.4	5.3
35-36	8.3	3.7	..	..	..	..	..	4.0
37-38	1.8	2.7	..	..	..	..	..	..
39-40	1.7	0.7	..	..	..	..	..	0.5
41-42	..	..	..	..	..	..	..	..
43-44	..	..	..	..	..	..	..	..

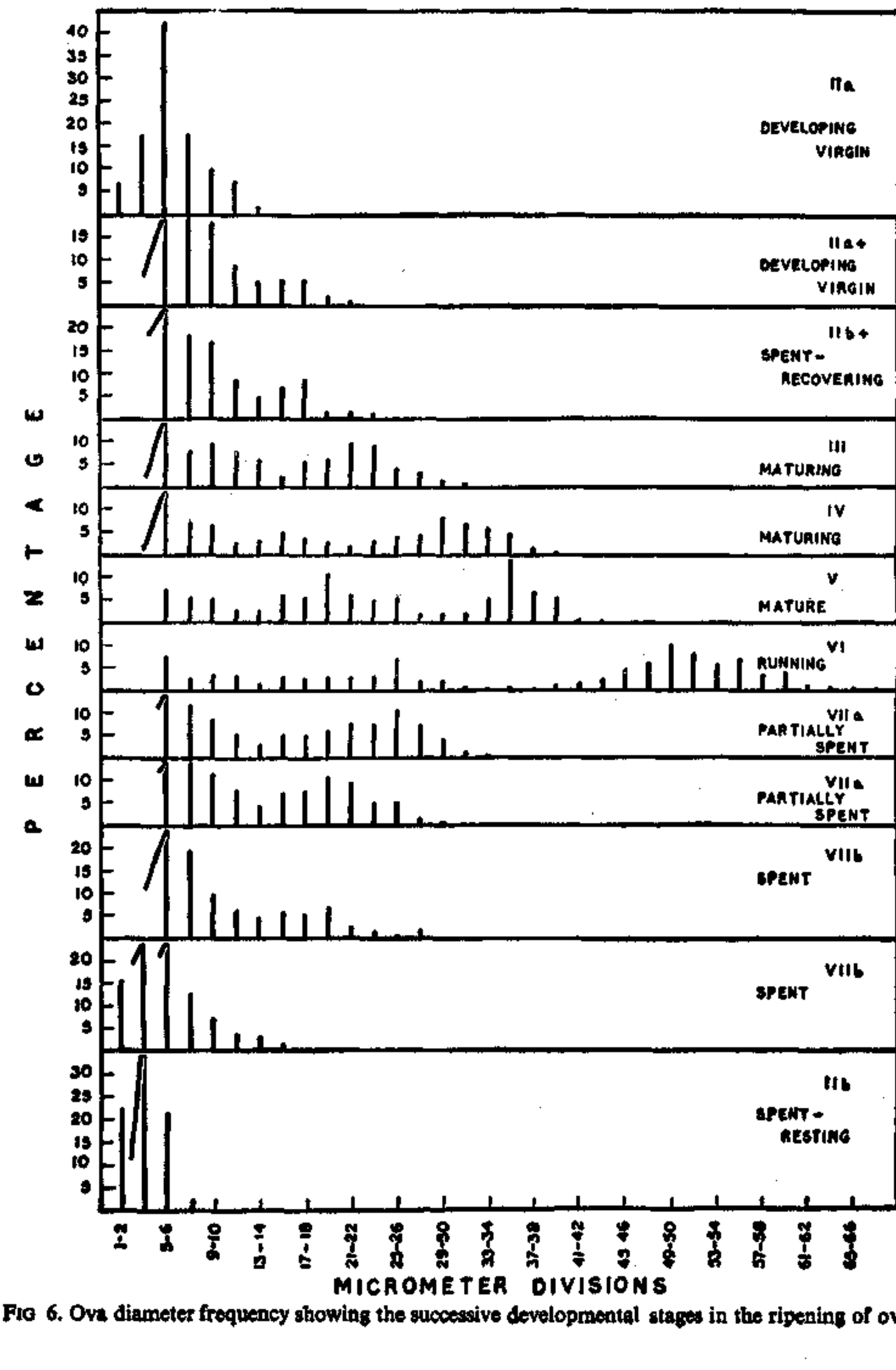

FIG 6. Ova diameter frequency showing the successive developmental stages in the ripening of ova

To give a composite picture illustrating the developmental stages in the ripening of ova from early virgin maturing or spent-recovering to spent-resting phases, all the stages are shown graphically in Fig. 6 which has no strict connotation of time, but some of the typical stages found during different years are inserted more for convenient presentation. It has been shown earlier (Antony Raja, MS. 1) that signs of sexual activity towards maturation are first seen in May. Thus, no clear mode of maturing ova is discernible in virgin maturing stage IIa in May although yolk deposition has started in some of the oocytes. Even in IIa+ clarity in modal formation is not so distinct as in IIb+ which is spent-recovering. However the formation of trough at 13 to 18 m.d. in stage IIa+ indicates that the foundation is laid for the withdrawal of a batch of ova towards maturation between stages II and III. Perhaps since IIb+ represents spent-recovering phase, maturing mode manifests itself quicker at 17-18 m.d. compared to virgin maturing stage. At stage III, the mode stands at 21-22 m.d. with indication of formation of another secondary mode at 9-10 m.d. Stage IV represents further growth in both batches of ova, the principal mode shifting to 29-30 m.d. and the secondary one to 15-16 m.d. At stage V, the two modes are respectively at 35-36 and 19-20 m.d. In stage VI the main mode is very much advanced to 49-50 whereas the second batch has a modal diameter of 25-26 m.d. This shows that while the secondary group has in fact registering growth progressively during the different stages, the interval between the two modes has been increasing as the maturity advances, thus indicating, that the growth in the second batch is not as rapid as in the principal batch. This is to be expected in any ovary which ripens ova in batches. The fact that in stage VIIa the modal diameter of the left over-ova is 25-26 m.d. clearly shows that the secondary batch has not been spawned along with the first. While the spent ovary of August carries a small mode at 19-20 m.d. representing the resorbing ova, that of subsequent date in September shows no modal representation at that level. The spent-resting ovary in stage IIb looks like an immature ovary in its ova diameter frequency.

Relative Number of Ova in Different Groups

It has been pointed out by Clark (1934) that analysis of ratios between the number of ova in most advanced group and the lesser advanced groups would give an idea of number of batches of ova that would be spawned in the same season and that if there is any progressive decrease in the proportionate number of smaller ova during the spawning season, it indicates that spawning takes place in batches. Following the general principles laid down by her, analysis has been made of all the ovaries in stages IV to VI for the relative number of ova in different groups. For this purpose, ova between 5 and 10 m.d. are designated as group A, those between 11 and 20 m.d. as group B, between 21 and 30 m.d. as group C and those above 30 m.d. as group D. Since group A represents immature oocytes with only slight traces of yolk formation, the other 3 groups are taken for consideration to calculate the ratios. The ratios of number of ova in group D to groups B and C combined together as well as the ratio of group D to group C alone are tabulated (Table XV). The ratio of number of ova in group D to B & C is calculated with the intention of finding out the ratio of all smaller yolked ova to all bigger yolked ova that are most likely to be spawned out as done by Clark (*loc. cit.*) June (*op. cit.*) and MacGregor (1957). Since it has been already shown that the secondary mode of ova around 25 to 30 m.d. is left behind in the ovary, the ratio between groups D and C are also worked out to find out whether there is any difference between the two sets of ratios. It is seen that, in general, the $\frac{B\&C}{D}$ ratio and C/D ratio follow the same trend, *i.e.*, comparatively, when the former is high, the latter is also high and *vice versa.*

TABLE XV

Ratios of smaller yolked ova to larger ones during 1959 *to* 1963

Date	Stage of maturity	$\frac{B+C}{D}$	$\frac{C}{D}$
1959			
26/8 . . .	IV	1.75	0.80
1/10 . . .	V	1.77	0.74
8/10 . . .	V	1.00	0.60
8/10 . . .	VI	0.62	0.35
8/10 . . .	VI	0.52	0.29
Average		1.13	0.56
1960			
13/6	IV	1.96	1.09
2/8	IV	2.15	1.03
2/8	IV	2.89	1.61
16/8 . . .	IV	1.27	0.29
18/8 . . .	IV	1.26	0.41
18/8	IV	1.89	0.92
18/8 . . .	IV	1.39	0.37
23/8	IV	1.10	0.49
Average		1.78	0.81

TABLE XV—*Contd.*

Date	Stage of maturity	$\frac{B+C}{D}$	$\frac{C}{D}$
1961			
3/6	IV	1.30	0.73
1/8	V	0.80	0.35
1/8	IV	1.07	0.49
1/8	IV	1.63	0.89
1/8	V	1.00	0.49
14/8	V	0.87	0.64
16/8	V	0.62	0.36
16/8	IV	1.20	0.84
16/8	IV	0.81	0.40
16/8	IV	0.94	0.51
23/8	IV	1.70	0.50
23/8	IV	1.81	0.64
26/8	IV	1.13	0.32
26/8	V	1.81	0.75
	Average	1.19	0.64
1962			
26/5	IV	1.42	1.02
26/5	IV	5.47	3.02
26/5	IV	2.20	1.36
17/7	IV	0.87	0.28
19/7	IV	1.46	0.60
30/7	V	1.01	0.24
30/7	V	0.96	0.51
3/8	V	0.70	0.50
3/8	IV	1.30	0.46
7/8	IV	2.05	1.05
7/8	IV	1.70	0.65
7/8	IV	1.49	0.46
10/8	IV	1.02	0.48
30/8	IV	0.75	0.45
	Average	1.60	0.78

TABLE XV—*Contd.*

Date	Stage of maturity	$\frac{B+C}{D}$	$\frac{C}{D}$
1963			
17/6	IV	2.30	1.37
17/6	IV	1.22	0.67
17/6	IV	1.63	0.84
17/6	IV	3.81	2.01
19/6	IV	1.42	0.91
19/6	IV	3.36	2.11
15/7	IV	1.18	0.35
15/7	IV	1.37	0.48
22/7	IV	1.34	0.35
6/8	IV	3.51	1.37
Average		2.11	1.05

Taking year-wise, it is seen that for 1959 the ratios progressively decrease from August to October. But this may be due to progressive growth of ovary from stage IV to VI, when the number of ova in the more advanced group increases with a corresponding depletion in the smaller sized ova. In 1960, when almost the entire data relate to August, there is a general decrease in the ratio $\frac{B\&C}{D}$ from 2 to 1 but this can also be attributed to advancement of maturity, for, although all of them belonged to stage IV, those in the latter half of the month have advanced further from typical stage IV and the ovaries weighed more than those of early August. For 1961, the $\frac{B\&C}{D}$ ratios for stage IV fluctuate between 1.81 and 0.81 and no progressive decrease is evident. In 1962 also there does not seem to be any decrease in the ratio in the ovaries of stage IV and whenever there is any decrease, it relates to stage V. For 1963, the ratios have been widely fluctuating from 3.81 to 1.18 for B&C/D ratio and 2.11 to 0.35 for C/D ratio. When month-wise averages are taken for different years, it is seen that there is no appreciable decrease in the ratios through time lapse for, the B&C/D ratio decreases for 1960 from 1.96 in June to 1.71 in August, and for 1961 from 1.30 in June to 1.18 in August. For 1962, although the ratio slumps from 3.03 in May to 1.05 in July and 1.29 in August, it is premature to stress too much importance to this for, not only data are very limited for May and July but the general decrease is to be expected from early developmental phase in May, when those which are differentiated would be fewer compared to large amount of smaller yolked ova, to the phase observed in July or

TABLE XVI

Average ratios of B+C/D and C/D for virgin spawners (VS) and recovering spawners (SR) of 1962 and 1963

Month	1962				1963			
	VS		SR		VS		SR	
	B+C/D	C/D	B+C/D	C/D	B+C/D	C/D	B+C/D	C/D
May	1.42	1.02	3.84	2.19	..	..	..	..
June	..	..	..	..	1.76	1.02	2.55	1.47
July	0.96	0.56	1.05	0.26	1.37	0.48	1.26	0.35
August	1.18	0.46	1.37	0.65	..	..	..	..

August, when the differentiation would have been marked and more ova would have been drawn from the stock of smaller ova. The decrease seen in 1963 from 2.29 in June to 1.30 in July can also be similarly attributed to the growth of ovary, for no signs of spawning having set in are seen in these ovaries.

Since as shown earlier, there were two distinct generations of spawners in 1962 and 1963, it was decided to analyse the ratios in these two groups to see whether there are any marked differences. The tabulated analysis (Table XVI) shows that in 1962, although there was a large difference between the 2 groups in May, the gap narrowed down considerably during July and August as the

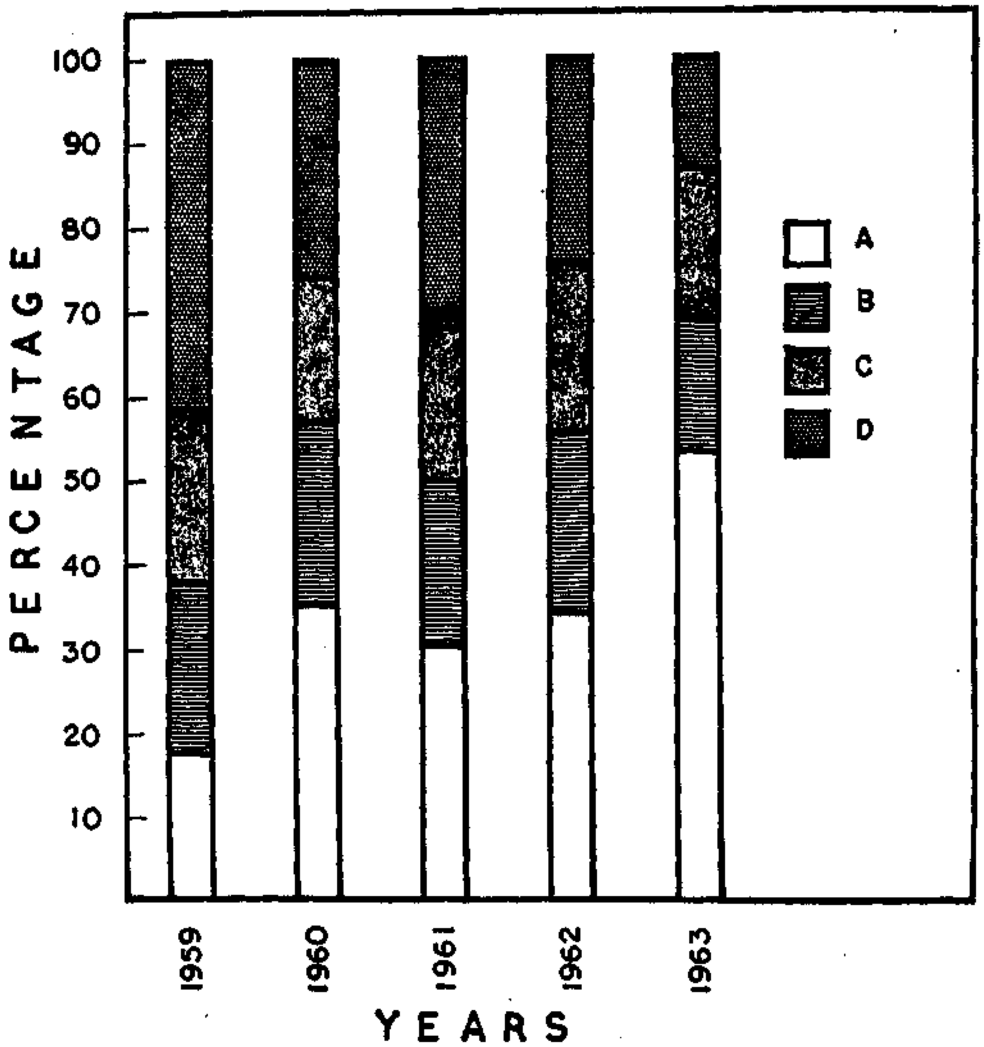

FIG. 7. Average percentage of different size groups of ova(A-5 to 10) m. d.; B-11 to 20 m.d.; . C-21 to 30 m.d.; D-above 30 m.d.).

spawning season is approached. The same was found to be true for 1963 also where the differences narrowed down from June to July. This probably indicates that the size or age of the spawners has no significant bearing on ratios between the different groups of ova.

Fig. 7 represents average percentage of the four groups of ova, mentioned above, in different years. The very high percentage of group D in 1959 is due to limited data in which stages V & VI have been better represented. Otherwise, there is rather remarkable similarity in the years 1960, 1961 and 1962 but 1963 data show that there is a very high percentage of immature oocytes of group A and that of group D is very low. When a thorough study of 1963 data is made, it is noticed that while uniformly the percentage of group A is high during all the months from June to September, the percentage of ova in group D is found to be comparatively more only in July.

Spawning Season

While describing the seasonal changes in the ovary weight, it has been shown by the author that signs of maturation are first seen in May with increased activity during June-July which reaches the maximum in August (Antony Raja, MS. 1). In a subsequent paper the author has also shown that stage IIa and III are available only in May and from June to August, stage IV is available in typical condition or a bit advanced further as stage IV+ while stages V or VI are usually found only during August and September (Antony Raja MS. 2). In Table XVII, the availability of different stages from IV to VIIb is presented and the percentages are graphically shown in Fig. 8. For this purpose, stages IV to VI are combined into one group to show maturing and mature condition while stages VIIa and VIIb are treated separately to illustrate the partially and completely spent conditions respectively. It is seen that although well-developed ovaries are available from May to October, the percentage of occurrence is only small during May when only a few fish have just reached stage IV, whereas majority have been still developing from immature condition to stages II and III. The availability of mature specimens during September and October is more influenced by data of 1959 and 1963, whereas no mature specimens have been noticed during 1960 to 1962 during these two months. The first signs of spawning are seen usually in the second half of July, when partially spent fish are available. The percentage occurrence of stage VIIa slightly increases in August, when fish in stage VIIb are also recorded in small numbers. In September, while incidence of stage VIIa is reduced, that of stage VIIb is increased. In October, stage VIIb is more common and during none of the years except 1959, mature fish have been obtained during this month. In November, while some fish are slowly resorbing the remnants of mature ova, the remainder are in spent-resting stage, IIb. Thus, the spawning season generally appears to be short from July to September, occasionally extending to October also with intense activity during July-August period.

FIG. 8. Percentage of maturing & mature, partially spent and completely spent fish during the different years.

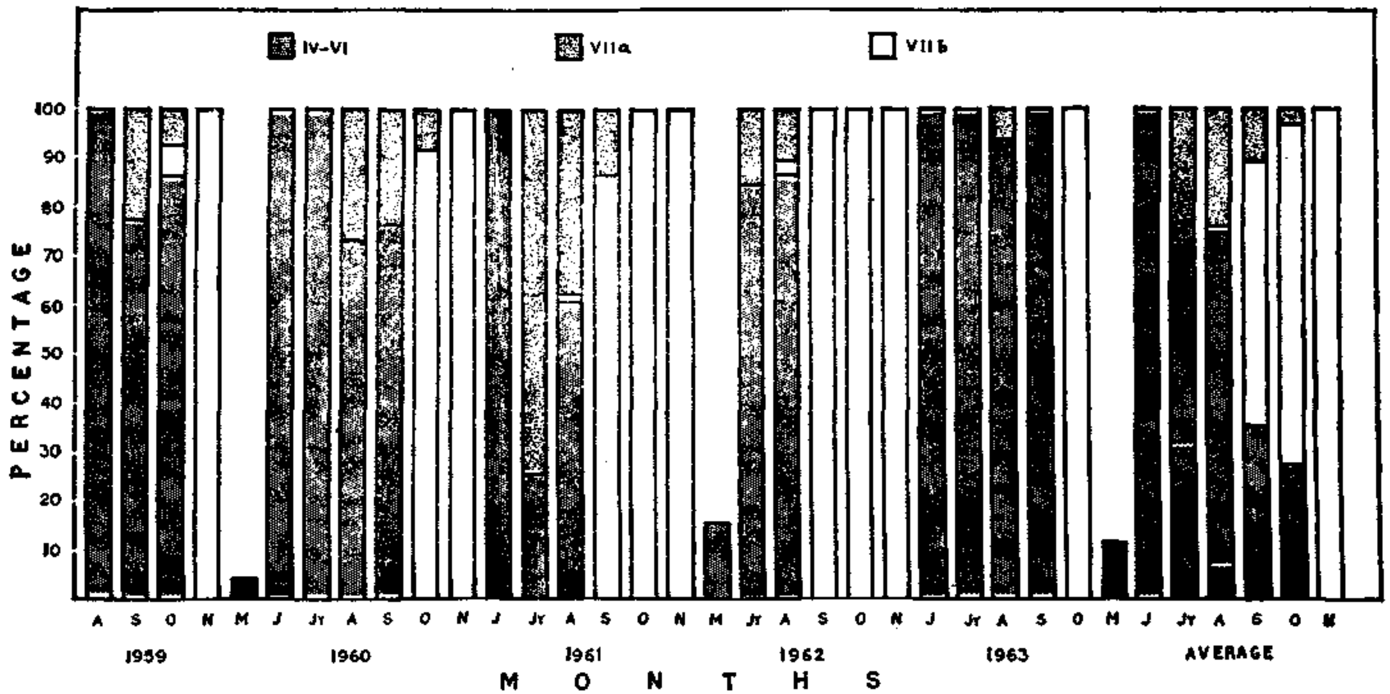

Table XVII

Availability of different stages of maturity during the years 1959 to 1963

Month	1959				1960				1961			
	No. obsd.	No. in stage IV to VI	No. in stage VIIa	No. in stage VIIb	No. obsd.	No. in stage IV to VI	No. in stage VIIa	No. stage VIIb	No. obsd.	No. in stage IV to VI	No. in stage VIIa	No. in stage VIIb
May	..	..	..	..	22	1	..	..	11	..	..	..
June	..	..	..	...	3	3	..	..	10	10	..	..
July	..	..	..	..	9	9	..	..	23	6	17	..
August	6	6	..	..	69	51	18	..	125	76	47	2
September	9	7	2	..	13	..	3	10	15	..	2	13
October	31	27	2	2	12	..	1	11	26	..	..	26
November	13	..	..	13	12	..	..	12	16	..	..	16

TABLE XVII (*Contd*)

Availability of different stages of maturity during the years 1959 to 1963

Month	1962				1963				Pooled for all years			
	No. obsd.	No. in stage IV to VI	No. in stage VIIa	No. in stage VIIb	No. obsd.	No. in stage IV to VI.	No. in stage VIIa	No. in stage VIIb	No. obsd.	No. in stage IV to VI.	No. in stage VIIa	No. in stage VIIb
May	76	12	..	..	..	..	..	..	109	13	..	..
June	..	..	..	..	25	25	..	..	38	38	..	..
July	47	40	7	..	24	24	..	..	103	79	24	..
August	55	48	6	1	17	16	1	..	272	197	72	3
September . . .	12	..	..	12	16	16	..	..	65	23	7	35
October	15	..	..	15	14	..	..	14	98	27	3	68
November . . .	10	..	..	10	..	..	..	..	51	..	..	51

MODAL SIZE GROUPS OF SPAWNERS

To see whether there is any growth in the spawners during the spawning season, the modal size progression of spawners was studied. The results are illustrated in Fig. 9, where the size intervals are classified into 5 mm. groups. In 1959, the spawners in August and September belonged to 175 mm. group whereas in October, the modal size shifted by 5 mm. to 180 mm. In 1960, when the modal sizes of potential spawners were watched, it was noticed that there appeared to be phenomenal increase in size from 145 mm. in May to

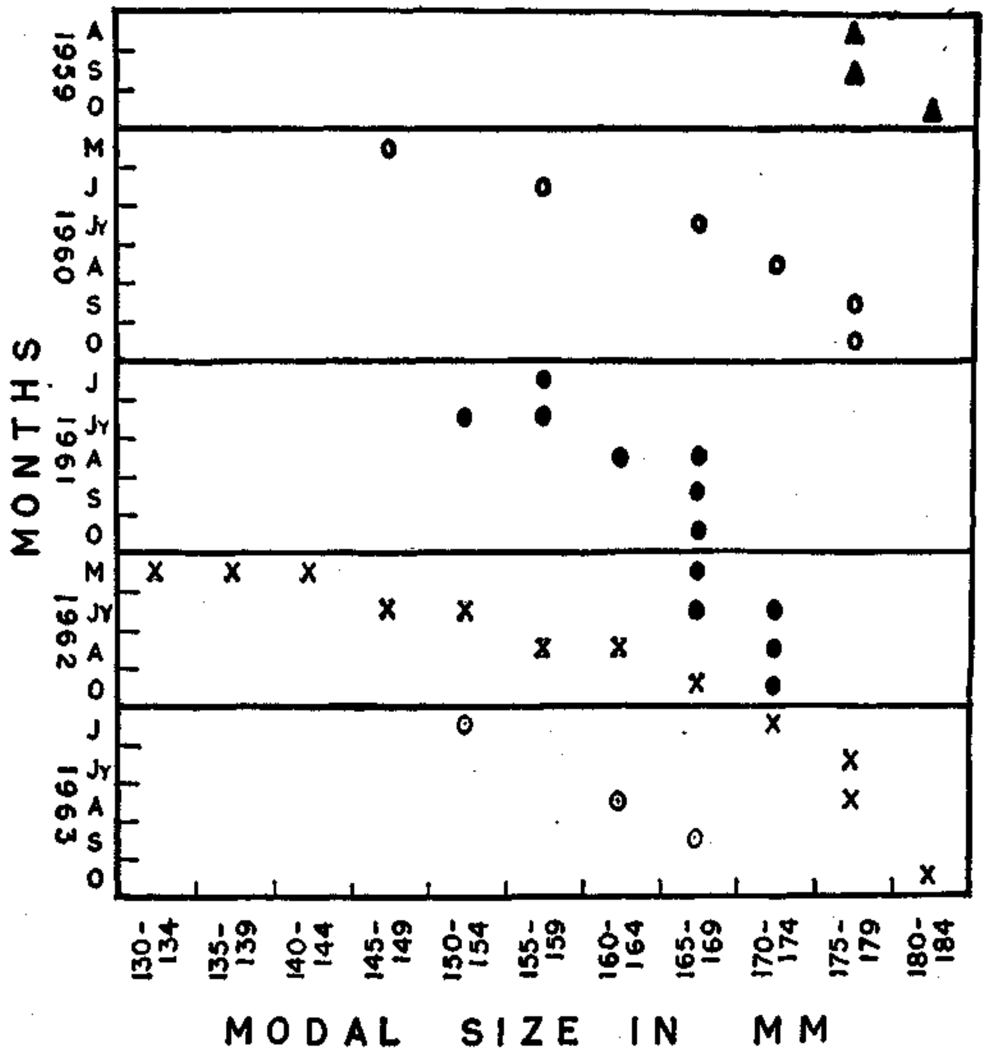

FIG. 9. Modal size groups of spawners during 1959 to 1963.

155 mm. in June, 165 mm. in July, 170 mm. in August and 175 mm. in September and October. Thus, an increment of 10 mm. each during June and July and 5 mm. each in August and September was observed. Subsequent to October there was no growth at all. In 1961, there was not such a rapid growth rate as seen in the previous year, but nevertheless there was distinct increment from 150 mm. in July to 160 mm. in August, whereafter the modal size was static at 165 mm. In 1962, the picture was entirely different, for not only the recovering spents of 1961 were noticed with a modal size of 165 mm. in May which progressed to 170 mm. and remained at that level in subsequent months, but another group, the virgin spawners, was also noticed. This group also recorded very rapid growth, something comparable to 1960. The modal sizes were fluctuating during the different weeks of May between 130 mm. and 140 mm. which were reflected in July and August also when the modal sizes progressed from 145 and 150 mm. in July to 155 and 160 mm. in August. There was a further increment of 5 mm. in October when the spent fish remained at a dominant size of 165 mm. In 1963 also this group could be traced during the spawning season with modal size of 170 mm. which increased to 175 mm. in August and September and ended up at 180 mm. in October. In addition to this group, which were spent-recovering spawners, there was as in 1962, virgin spawners which appeared to register slightly faster growth than the other group for, the modal size of 150 mm. in June progressed to 160 mm. in August and to 165 mm. in September. Thus it appears in general that the virgin spawners record more rapid growth than the recovering spawners during the spawning season and that there is almost no growth between October and subsequent May, when the spent fish are in resting phase.

Discussion

Nair (1959) has illustrated graphically the ova diameter frequencies of three ovaries belonging to stages IV, V and VI. His observations show only one mode of maturing ova for stage IV at 23-24 'microns' (0.45 to 0.47 mm.). In stage V, the picture is almost the same except that the differentiated batch of eggs show a modal diameter of 25-26 'microns' (0.49-0.51 mm.) and a few transparent eggs at 51-52 'microns' (1.00-1.02 mm.). In Stage VI, however, there are two modal groups, a more advanced one of ripe ova with a modal diameter of 49-50 'microns' (0.96-0.98 mm.) and a secondary one of maturing ova at 21-22 'microns' (0.41-0.43 mm.). (The use of the term 'micron' to denote micrometer division in the above cited work is a bit confusing for. a micron is only one thousandth of a millimeter). Unlike these earlier observations, it has been seen during the present investigation that except in the case of virgin spawners in 1962 and which as recovering spawners appeared in 1963, there were two batches of maturing ova in stage IV. Moreover during all the 5 years stage IV ovaries had the more advanced mode at 29-30 m.d. (0.53-0.55 mm.). Hence, it appears that the ovary designated as stage IV in

Nair's material is comparable to a certain extent to stage III+ of the present investigation. It is very surprising that in stage V of Nair's material there is such a vast interval between the transparent eggs which form hardly 1% of the total number examined and the opaque ova which form a mode. Although the latter have just advanced by 2 m.d. in modal diameter from those found in stage IV, Nair, for reasons not very obvious, calls them 'mature' while in the earlier stage they are referred to as 'maturing'. During the entire course of the present study, stage V ovaries never presented such an appearance of long interval in size between the transparent and opaque ova and the size increase was only gradual and never sudden. However, it is not very clear how a stage V ovary happened to have such a wide difference in the size of the two types of ova. Whether the small batch of eggs were actually unspawned remnants of spawning and hence it was a stage VIIa ovary or the differentiation of such a small percentage of ova is due to some spoilage in the ovary because of decomposition as has been observed on certain occasions during the present study or the causal factor is something dicerent, cannot be underlined. In stage VI ovary of his collections, a secondary mode has suddenly appeared without any indication of its formation in the earlier two stages. If, as Nair contends "the ripening of eggs is accomplished very quickly", then in stage VI also, there should have been only one mode, that is, those ova which formed a mode at 25-26 m.d. in stage V should have grown into ripe ova with modal diameter at 49-50 m.d., for, it is well known that just prior to spawning, most of the energy is utilised for the growth of already differentiated mature ova and that very little growth takes place in the immature oocytes or intermediate ova, but on the other hand there is a secondary mode at 21-22 m.d. The author has further stated that "......... since the actual process of ripening is completed rapidly it is to be expected that the remaining mature eggs also will become ripe and extruded along with the already differentiated ripe eggs". It is not quite clear what he actually refers to as "remaining mature eggs", for, if it is intended for the batch of maturing ova at 21-22 m.d. then the use of the term 'mature' is unfortunate. Moreover, no proof has been adduced that this second batch of ova would also be rushed through and spawned out along with the other eggs. The time that would be taken for the second batch of ova around 21-22 m.d. to ripen to about 50 m.d. or above has obviously been thought to be of insignificant duration for it is well known that no time would be lost before the ova are spawned out once they are differentiated and become transparent. Since Nair has not recorded partially spent fish, perhaps, it has been taken for granted that this second batch is also spawned out along with the major group. Thus, while the presence of two modes in stage VI of Nair's material is real, it has been shown during the present study that the secondary batch is not spawned out alongwith the more advanced batch, as Nair thought it to be the case, but is left behind as seen in the partially spent ovaries.

Thus, the next question, we are confronted with, is whether, in view of the presence of partially spent fish with a batch of unspawned opaque, maturing ova, a subsidiary spawning takes place in the same spawning season in individual fish. Clark (1934) bases her case for multiple spawning in California Sardine on four lines of evidence, namely, "The multiplicity of modes in the ova diameter frequency curves; the high degree of correlation between the growth of these successive groups of eggs; the occasional presence in the ovary of a few ripe unspawned eggs accompanied by a new ripening group and the decrease, as the breeding season advances, in the numerical ratio between succeeding batches of eggs and the largest size group ...." June (*op. cit.*) also has based his conclusion of more than one spawning in yellowfin tuna on the same four evidences. Let the first criterion be taken now for analysis. Buñag (*op. cit.*) working on the spawning habits of three Phillipine tunas, found that the ova diameter frequencies show almost the same pattern in all the three species wherein before spawning the frequency curves show two distinct modal groups of ova, one ripe and the other, maturing. The recently spawned ovaries are left out with the secondary mode still in the ovary and discussing whether this group of eggs will eventually mature and be spawned or degenerate and be resorbed, the author comes to the conclusion that they are eventually spawned. He is of the opinion that after spawning the ovary reverts back to stage III, then develops again to stage VII, which cycle is repeated several times in the spawning season before the ovary starts its resting phase. But it should also be borne in mind that these species do not have a well-defined spawning season, for, ovaries of all stages of maturity, except VI, could be collected at any time of the year. In the case of *Neothunnus macropterus*, June (*op. cit.*) has also concluded more than one spawning in the same season for individual fish but here also the season is a protracted one from May to mid November. In big-eye tuna, *Parathunnus sibi*, Yuen (*op. cit.*) has recorded more than one batch of ova developing in the ovary as well as ovaries with residual eggs in both early and late stages of resorption. The only fact, which has prompted him to suspect two spawnings in close succession, is the incidence of four ovaries with residual eggs in early stages of resorption together with developing eggs in the late maturing or mature stages. In *Sardinops caerulea* where Clark (*op. cit.*) has demonstrated multiple spawning, the spawning season extends from February to August and the availability of fish belonging to advanced maturity in considerable percentage from January to August coupled with the incidence of spent fish from April to November perhaps indicate that there is enough time for three or more batches to ripen and spawn out successively as Clark contended. But this was seriously questioned by MacGregor (*op. cit.*) who critically analysing her data as well as his own on the same fish has concluded that the average number of batches spawned may be between 1 and 2.5 only, which means that he has not ruled out the possibility of spawning even one batch and hence, he was unable to conclude from the study of his material as well as evidences presented in the literature by various authors regarding the number of batches that are spawned by sardine in the same spawning season. The three species of osmeridae studied by Hart and McHugh (1944) show interesting differences worth recording here. As these three species spawn in inshore waters, their spawning habits are better known than those which breed offshore. Their studies have shown that in the case of *Thaleichthys pacificus*, there is only one mode of ripening ova with only one known spawning and in *Hypomesus pretiosus*, there are several batches of developing ova with direct evidence on multiple spawning but in *Mallosus catervarius*, although the size frequencies of the eggs suggest that the mature fish spawns more than one batch of eggs, there is no evidence whether any second spawning occurs. Similarly, although two modes are present in anchoveta, *Cetengraulis mysticetus*, Howard and Landa (*op. cit.*) have ruled out the possibility of more than one spawning, for, during the developmental stages, the secondary mode has been more or less stationary while the principal mode has been recording growth and a third mode never appears to justify the release of eggs in batches. The spawning season for this fish is short, from October to January, with intense activity during November and December. In the recent study of Qasim and Qayyum (1961) on the spawning habits of fresh water fishes, it is seen that in those fishes which exhibit more than one batch of maturing ova, their breeding seasons are prolonged, sometimes even throughout the year or there are more than one spawning season within a year from which the authors have drawn the conclusion of multiple spawning. Thus, from the presence of more than one batch of ova in the ovaries, it cannot be conclusively said that there is more than one spawning per individual during the same season unless the season is found to be prolonged and different maturity stages of developing phase are present at any given time showing a considerable overlapping. It has been shown earlier that the spawning season for oil sardine is not prolonged but one of short duration with intensity during July and August and that stages IV and V are available mostly during these two months only.

Regarding the second of the criteria postulated by Clark (1934), namely, high degree of correlation between the growth of successive groups of eggs, since MacGregor (*op. cit.*) has expressed doubt concerning the interpretation of these correlations because of the mathematical restrictions imposed on plotting always the larger diameter on one axis and the smaller on the other, which limits the plots to a triangular area rather than a rectangular area, no attempt has been made during this study to see whether there is any correlation between the two groups of maturing ova.

The third evidence advanced by Clark (1934) and agreed upon by June (*op. cit.*) and Buñag (*op. cit.*) is the presence of ripe unspawned eggs along with new maturing group of ova. In their fiishes the spawning season was found to be protracted and the second batch had been found to progress towards maturity when the resorbing eggs were present and in addition, it should also be remembered that more than one secondary mode were present in the ovaries of these fishes. Perhaps the spawning rhythms and other biological conditions in these fishes may point towards the conclusion the above authors have drawn from their material. However, it may be pertinent to draw attention to a few points of debatable nature from the observations of above workers. Although Clark (*loc. cit.*) observes that remnants of ripe eggs were found scattered in the mature ovaries at the same time a second batch was developing towards maturity, these were, even according to her, limited to a few instances and detection of remnants of ripe eggs was rendered difficult. In June's investigation (*loc. cit.*), although 50 ovaries belonging to advanced maturing and mature stages were examined only in 8 cases remnants of mature ova were found — one out of 14 in June, none in July when 11 were examined, 1 out of 8 in August, none in September and 5 out of 11 in October and 1 out of 2 in November. The spawning season of yellow-fin tuna in Hawaiian waters was found to extend from mid May to November with intense activity from mid June to August. Thus, more instances of unspawned eggs were noticed after the peak spawning season. Buñag (*loc. cit.*) does not give the number of instances of degenerating ripe eggs but observes that frequently they have been encountered in stage V ovaries of *Neothunnus macropterus*. Advancing this as evidence of multiple spawning, he states, "The fact they are encountered even in Stage V ovaries indicates the relatively short time it takes for the maturing group of 12 to 17 micrometer units in the spent ovaries to develop to the distinct batch in Stage V ovaries with a diameter range of 17 to 24 micrometer units". But this is rather surprising, for, earlier on pg. 155 he has stated that "No stage V ovaries of *Neothunnus macropterus* were collected" nor the tabulated records of ova diameter frequency for the same fish in different stages show stage V. By comparing the condition of stage V ovaries in the other two fishes studied, he has constructed the missing link. Since he has also not established the presence of such remnants in other fishes, the suspected short time interval for the maturing group of ova to develop to advanced condition is more a conjecture than a direct observation. The partially spent phase, stage VII, in *Neothunnus macropterus* showed that the secondary batch had been left out. Buñag's contention that this second batch of half-ripe ova would develop to maturity and after repeated cycles from stage III to VII and back, the ovary might start resting at the end of spawning season in stage VII-A, may, however, hold good under other circumstances and other biological features found in the fish, a knowledge of which the present author can not have, but whether the presence or absence of resorbing eggs can be adduced as an evidence of more than one spawning appears to the present author as doubtful and not a safe criterion for, even during present investigation in stage V ovaries such large disintegrating, transparent, semi-transparent and translucent ova were seen, shrunken and shrivelled, along with droplets of oil glouble scattered throughout the ovary and also a few empty egg shells were found. But the author has already shown that these are atretic eggs in the ovary, a feature that happens occasionally even before spawning starts (Antony Raja, MS. 2). In none of the works cited above, the possibility of follicular breakdown in advanced ovaries has been reported although such a phenomenon has been recorded very common in many teleost ovaries (Hoar, 1955; Pickford and Atz, 1951). While the degenerating eggs reported by earlier workers may be actually remnants of spawning, the possibility of incidence of *Corpora atretica* has not been taken into consideration and so, cannot be ruled out. Hence, it may not be a fool-proof evidence to construct a picture of more than one spawning based on the presence of unspawned eggs. It is interesting in this context to note that MacGregor (*loc. cit.*) who made exhaustive comments on the criteria set out by Clark (*loc. cit.*) has not attempted to analyse this evidence alone.

As regards to the fourth evidence of progressive decrease in the numerical ratio between the more advanced group and the remaining smaller yolked ova, it has been shown that there is no appreciable decrease in the ratio during the spawning season in the ovaries belonging to the same stage of maturity and whenever there is any decline, it is more due to advancement of maturity from stage IV to stages V and VI and not due to second ripening after releasing the first batch of ova. The average $\frac{+}{D}$ ratio of 1.5 : 1 shows that if a portion of these degenerate, as has been observed due to atresia, then an average of 1 to 2.5 batches develop in oil-sardine ovaries. The average C/D ratio for the first 4 years is 0.7 : 1 and for the entire 5 year period 0.8 : 1 which gets progressively reduced as the maturity advances to about 0.25 to 0.30 : 1 in stage VI, thereby indicating that the number in the group of 21-30 m.d. is too low to form another batch for subsequent spawning.

Citing the evidence of Andreu (1951) who observed that the peak spawning season of European sardine was too restricted in time to allow the fish to mature and spawn more than one modal group of eggs in the same spawning season, MacGregor (*op. cit.*), inspite of the fact that multiple spawning had been established in California sardine by Clark (1934), inferred such a possibility for the same fish. In the case of oil-sardine, it has been shown that the spawning season is normally spread over for 3 months from July to September of which the peak spawning is restricted to first 2 months only. While this study offers no scope to specifically delimit the time interval taken for the ovary to progress from stage IV to VI, the availability of stage IV from June to August with variations in the size of the more advanced modal group from 27-28 m.d. to 35-36 m.d. coupled with large percentage of partially spent condition in late July to August end, it can be roughly deduced that at least one to one and half month is required for stage IV to progress to stage V. The availability of stage VI along with stage V and V+ in 1959 shows that once stage V is reached, no time is lost before spawning. Hence, if the partially spent ovaries which resemble stage IV ovaries with the modal diameter less than 30 m.d., were to recover again, it would roughly take another month which means that recovering mature ovaries should be available in September-October period also which in turn should also present signs of previous spawning. But on the contrary, while no such ovaries are available during September-October period in most of the years of the present investigation, even the rare material obtained during this period do not present any evidence of having recovered from previous spawning and may represent stray cases of late spawning. So, it is rather doubtful whether the fish will have enough energy to recover and spawn the remaining eggs once again. The presence of three modal groups in a partially spent fish at 9-10, 15-16 and 27-28 m.d. in September 1959 (Table X) and the presence of only 2 modes in a completely spent fish of October 1959 with modal diameters of 9-10 and 19-20 m.d. may tempt to speculate whether the group of ova seen at 27-28 m.d. is not likely to have been spawned out in a second act of spawning. But based on such limited material as one or 2 ovaries in a year when maturing conditions during earlier months of June and July are not known, it would be rather premature to form any opinion when other factors may point towards a negative view. Thus, while it can be decisively said that there is fractional spawning in oil-sardine, it cannot be indicated beyond reasonable doubt about the possibility of second spawning in the same season. Chances appear to be more in favour of degeneration and resorption than maturation in the case of unspawned ova. This can be clearly illustrated when attention is switched over to Table XII for the data relating to 1961 when on a single day, 14-8-1961, stage V, VIIa and VIIb occurred (stage IV+ was also available that day, but not included in the table). The three ovaries in stage VIIa show the modal diameter of remaining unspent ova at 25-26, 23-24 and 19-20 m.d. respectively. Since stage VIIb was also available on the same day in which no clear mode of remnants is discernible and considering the fact that in stage V ovary, the secondary mode stands at 25-26 m.d. and the finding during 1959 that there is very little growth in the second batch when the ovary grows from stage V to stage VI, it appears more logical to treat such a progressive decrease in the modal size as due to degeneration and resorption than considering them as progressive increase in the modal size, especially in view of the fact that in the fresh condition, the ovary with the largest modal size of unspawned eggs had a few large translucent ova measuring 40-42 m.d. undergoing degeneration, which indicates that spawning had been more recent in this ovary compared to others. In the ovary with the next decreasing modal size, large empty egg shells were present, whereas in the case of the ovary with the smallest modal size, only brownish masses characteristic of completely spent ovary were noticed. In the completely spent stage VIIb of the same date, the opaque ova above 20 m.d. were very few which gave unhealthy appearance in grey colour with yolk in the form of small spherules giving it a sieve-like appearance. Oil globules were seen scattered throughout the ovary in all these cases but they were more in the recently spawned ovary. In this context the observation of June (*op. cit.*) on the residual unspawned eggs may be recalled. He states "Among these remnants, some of the ova were greyish in colour with the shell membrane partially collapsed; in a few oil globules were still discernible; and in others only the transparent shell membranes or fragments of the shells remained". Later Yuen and June (1957) describing the resorption of residual eggs in the same fish observe "Immediately after spawning, these residual eggs generally resemble ripe eggs, except that they become shrivelled owing to the shrinking of yolk mass and the resulting collapse of the chorion. The oil sac is usually ruptured and the released oil appears as bright yellow droplets. The eggs at this stage are still loose and translucent. Subsequently the eggs loose their translucence ....". Thus, while the similarity in the observations on the nature and appearance of resorbing eggs of these workers and the present author cannot be missed, at the same time the conclusions drawn by the above authors cannot be applied to oil-sardine, for, it is the occurrence of these early stage residual eggs throughout the year which has influenced the above authors to indicate year-round spawning activity with release of eggs in batches, whereas in the case of oil-sardine, incidence of these eggs is noticed mostly in July and August and that too they may be present only for a short time in individual fish, being resorbed that quickly. Even in California sardine where multiple spawning was established, Clark (*loc. cit.*) cites the unpublished manuscript of Andrews, who was working at the same time on the same fish on the cytological changes that occur within the ova wherein the author has favoured the idea of degeneration and resorption of ova belonging to secondary modes than the possibility of their ripening and spawning in batches. Finally, it may be pointed out here that, Hornell and Nayudu (*op. cit.*) although recorded partially spent ovaries in September and October, hesitated to formulate any explanation, for they presumed that if they were partially spawned, then the reproductive products should ooze out on pressure. But it is well known that remnants of ova need not ooze out in partially spent ovaries unless the spawning act had been so very recent and it has been shown that resorption takes place fairly quickly. Because they did not find any shoals of juveniles entering the inshore waters after September, they were rather reluctant to admit the gonads as partly spent, thinking probably that if they were partially spawned, then the fish should release the remainder of ova also in the same season but which was impossible since they had fixed the spawning season from June to August. But since it is now known that the possibility of secondary spawning in the same season is very remote, the absence of juveniles entering the inshore waters after September is only to be expected and natural and it is confirmed that what they doubted as partially spent gonads were really so.

It may be recalled that while recording observations on the relative numbers of ova in different groups, it has been pointed out that the 1963 data show a very high percentage of immature oocytes of group A and a low percentage of ova in group D. This may probably indicate that the amount of spawning in general would have been comparatively poorer in 1963. Incidentally when an analysis of instances of follicular break down was made, it showed that while 11.5% of the cases had experienced atresia in 1961, the percentage was higher in 1962 with 19.6 and it reached the highest in 1963 with 29.3. Since follicular breakdown naturally would reduce the number of ova ready for spawning, such a high rate of atresia in 1963 coupled with a very low production of mature ova above 30 m.d. probably would have resulted in very poor spawning in that year. Again, while the average $\frac{B+C}{D}$ and C/D ratios are within comparable limits for the years 1959 to 1962, they were very high for 1963. While this may further throw more light on the possibility of lesser ova being earmarked to be released, it is absolutely necessary that very great caution is exercised on expanding this evidence further. However, it is indicative to a certain degree that, if the fishery is a failure in 1963, then the causal factor can to some extent be traced to this peculiarity in the ovaries of 1963.*

Regarding the spawning season of oil-sardine there seems to be some elasticity in the periods recorded by earlier workers. Hornell (*op. cit.*) found mature fish from June to end of August which was corroborated by the studies of Hornell and Nayudu (*op. cit.*) who concluded that spawning takes place from June to August but Devanesan (*op. cit.*) doubted the accuracy of earlier findings and extended the spawning season by two more months up to October based on the occurrence of specimens which had just spawned and others in various stages of being spent. During his investigations, Nair (1959) had seen mature ovaries mostly during July-August period and occasionally in September. Only for one year, 1950, spawners with mature gonads were available till November. Based on this observation and collection of planktonic eggs in August-September period, he concluded that spawning season is one of protracted nature with intense activity during August and September. The present observations accord, in general, with the findings of Nair (*loc. cit.*) but it cannot be said that spawning season is protracted in oil-sardine for, although during occasional years adult fishes with advanced gonads had been collected in October by Devanesan (*loc. cit.*) for 1934, Nair (*loc. cit.*) for 1950 and by the present author for 1959, they may be better treated as exceptional cases rather than as a rule, for, the spawning seasons are subjected to considerable changes occasionally, due to environmental conditions and it is also possible that individuals examined during these years may be late spawners. It has also been shown by the present author that the percentage gonad index, *i.e.*, gonad weight expressed as percentage body weight of the fish, rises steeply during June and July and reaches the peak in August only to fall in September as steeply as it has risen up with a further decline during the subsequent two months (Antony Raja, MS. 1). This decline during October and November may be due to resorption

*Since submitting this paper for publication it has come to light that the fishery was indeed failure in 1963.

of remnants of ova from stage VIIa to Stage VIIb. Hence, July to September, a period of 3 months may be considered the spawning season of oil-sardine with intense activity during the first 2 months. During occasional years it may be advanced by a month or prolonged to another month.

The records of 1962 and 1963 are clear evidences to show that the oil-sardine are able to recover from spawning and enter the spawning season for the second time in their life time. It is also seen that among the spawners, it is only the virgin spawning group that record a rapid rate of growth during the season whereas the recovering spawners only add 5 or 10 mm. to their pre-spawning season size. Perhaps in the earlier years of 1960 and 1961 also there might have been two succeeding generations in the spawning season but which would have been failed to be noticed, one of the reasons for which may be the differential growth rate in the two successive year classes. Since the recovering spawners constitute comparatively smaller percentage as has been found for 1962 and 1963, it is possible that they have been present in 1960 and 1961 also, for, during these years the size range of spawners examined was large enough, 146 to 202 mm. for 1960 and 153 to 195 mm. for 1961, to have accommodated a few individuals of larger size belonging to recovering spawners group. Since the growth rate of the immature fish recruited to the commercial fishery in 1961 and 1962 has been very poor, the dominant size during the seasons being 100-110 mm. in 1961 and 110-120 mm. in 1962 unlike the modal size of 140 mm. in 1959 and 1960, the difference between the two successive year classes in the subsequent spawning seasons for 1962 and 1963 was too glaring to escape notice. The rarity of spent fish of recovering spawners group from September onwards probably indicates that they reach the end of their life span after going through two spawning seasons.

Tracing the growth of three generations during 1921-1922, Hornell and Nayudu (*op. cit.*) found that generation B grew from a total length of 140 mm. in December 1921 to 170 mm. in subsequent June and to 180 mm. by end of September during which time these fish had gone through the spawning season. (The above authors had recorded the size group in standard length and in cm. but for comparative purposes, they have been converted into total length and in mm.). Generation A which was spent-resting and which was seen with a modal size of 180 mm. during December 1921, recorded only an addition of 10 mm. by the end of subsequent June, after which they occurred as stray spent individuals in August. Thus, these authors also had found two successive generations entering the spawning season and recorded a growth of 20 mm. in the case of virgin spawners (generation B) compared to 10 mm. for the recovering spawners (generation A). From the published length frequency data of Chidambaram (1950), it is seen that spawners recorded a growth of 30 to 50 mm. during the spawning season. In the absence of such detailed presentation of length frequency data month-wise for spawners in the published accounts of Nair (1954 & 1959), nothing decisive can be traced about their growth rate during the season. However, the results of the present investigation bear corroborative evidences of acceleration of growth rate in the spawners during the season and that increment is greater in virgin spawners as compared to recovering ones.

While Hornell and Nayudu (*op. cit.*) observe that oil-sardine attain sexual maturity at an average size of 150 mm. which found agreement with Devanesan (*op. cit.*) who has recorded spawners in the size range of 150 to 170 mm. which contained oozing individuals also, Nair (1954), objecting to the conclusion of earlier authors on the size at first maturity, states, "The earlier authors appear to have made no distinction between the conditions found in the gonads reaching maturation and those ready for spawning for they appear to have assumed that spawning takes place immediately after the gonads attain the normal size, which according to these authors takes place when the fish reaches a size of 15 cm. in length". By this, the author appears to imply indirectly that either there is a long time interval between maturation of gonads to normal size and the actual act of spawning for which no proof has been adduced or he has assumed adolescence setting in those ovaries belonging to smaller sized fish. While adolescence may be a feature in temperate fishes like hake (Hickling, 1930) or Norway pout (Gokhale, 1957), its incidence in a tropical fish which has a short life span is highly unlikely. Further, it has been shown in the present study that smaller sized fish not only enter the spawning season with well-developed gonads but are obtained as spent during the spawning season. The smallest spent fish, thus recorded, was 147 mm. in total length on 27-7-'63. Although the smallest mature specimens recorded by Hornell and Nayudu (*loc. cit.*) relate to June, Devanesan's materials obtained so near the end of spawning season clearly show that it can not be presumed that the fish will release the sexual products only after they reach still larger size. Nair (*loc. cit.*) further adds, "The present study has shown that the one-year old sardines are always indeterminate with undeveloped gonads, while the two-year old oil sardines are immature with the gonads usually in the earlier stage of development. Active spawners and spent oil sardine in stages V-VII have always been encountered in the three-year old oil sardines only". Since the age of the fish is another debatable problem, discussion may be confined to the sizes, which, according to him, are 10, 15 and 19 cm. at the end of first, second and third years respectively. This means that 15 cm. fish are only immature. There would have been some justification to question the onset of maturity or spawning or adolescence in fish of 15 cm. size if Nair has recorded atleast maturing fish in the 15 cm. group or resorbing gonads in the fish of the size range 15 to 19 cm. On the other hand, it would have been normal if he has doubted the size of the spawners and not the potentiality of spawning in the smaller fish as recorded by earlier workers. The confusion could have been avoided had the growth rate of the spawners during the spawning season also been taken cognizance of. It is likely that those fish in 150 or 160 mm. group in May or June might have recorded another 20 mm. during the season, for, Nair himself has recorded active spawners from 17 cm. group onwards. Thus, the present observations on the size at first maturity are in conformity with the findings of Hornell & Nayudu and Devanesan. It may, however, be added that during the years of poor growth, the size at sexual maturity may be around 150-160 mm. and during the years of normal growth increments, the size may be 10 to 15 mm. more. It depends upon the prevailing ecological conditions during the previous year when they are recruited to the commercial fishery in the immature state. If larger sized immature sardine are recorded during September to December of a particular year, then the size at the succeeding spawning season will be larger than in a season when poorer growth is recorded in the immature fish.

Before concluding the discussion, it may not be out of place to record a few remarks on the possible location of spawning grounds although no direct evidences have been collected on eggs and larvae. Hornell (*op. cit.*) has observed 1 inch fry off Calicut and 1½ inch fry off Tellichery but he has not recorded the depth or area at which these have been observed. Devanesan (*op. cit.*) has collected oil-sardine eggs off Quilandy coupled with which the occurrence of spawners in oozing state caught at 11-12 fathom area probably indicates a spawning ground off Quilandy. Although Nair (1959) has collected oil-sardine eggs off Calicut and has studied the early developmental stages, he has not given the area of collection. However, he states, "......... the spawners which enter the foreshore waters immediately after the commencement of monsoon disappear during the post-monsoon period for spawning in deeper waters ......" (Pg. 343) but later there appears to be some contradiction, for on pg. 347 he remarks, "The shoreward migration of the spawners is, therefore, believed to be for spawning only". During the present investigations, one sample in 1959 with oozing individuals was supposed to have been caught off Tanur, about 20 miles south of Calicut, at 14-15 fathom area. In 1961, nearly ripe specimens in stage V and recently spawned fish with remnants of large unspawned eggs in stage VIIa were obtained off Puthiangadi, about 2 miles north of Calicut at 10-14 fathom depth. In 1962, juveniles belonging to 60 mm. group were drawn along with anchovics in the *nethal vala* operated off Calicut at 13-14 fathom area. Again in 1963, very small fry of the size range 15 to 25 mm. were reported along with juvenile mackerel and anchovies at the same area in the same gear. Although it may only amount to speculation, the observations of earlier authors and the present records appear to indicate that spawning probably takes place in the area covered between Quilandy and Tanur at about 15 fathom line and from the rarity of gonads in stage V and the non-availability of running specimens from the fishing area up to 10 fathom, it may be safely assumed that spawning takes place beyond the present fishing belt.

SUMMARY

Observations on the spawning habits of oil-sardine, *Sardinella longiceps* have been made based on the ova diameter frequency method on the materials collected from 1959 to 1963. 2% formalin has been found ideal both for proper preservation with minimum distortion in the shape of the ova and for easier removal of ova from the ovigerous lamellae.

Preliminary investigations made on the ova diameter distribution in the ovaries to determine the sampling procedure have resulted in the following findings: (1) There was no significant difference in the frequency distribution of ova diameter between anterior, middle and posterior regions of an ovary except for 1959 and 1962 materials nor was there any significance between positions like periphery, mid-region and centre within different regions in any year; (2) the difference in the distribution of ova diameter between the right and left ovaries is negligible; (3) there is no significant difference in the relative number of opaque ova in the different regions and (4) it is immaterial whether subsampling consists of 1,000 or 300 ova for measurement.

The ova diameter frequencies show bimodal appearance for maturing and mature ovaries. Although both the batches of ova record progressive growth, it is found to be more rapid in the more advanced mode. It is found that the second batch of ova is not spawned out along with the already differentiated ova but retained after spawning in the partially spent ovaries. The question of more than one spawning in the same season for individual fish is discussed in the light of evidences available and the observations of earlier workers and the conclusion drawn is that chances are very remote for secondary spawning in individual fish in the same spawning season but more for the second batch of ova to disintegrate and get resorbed.

The relative number in different size groups of ova does not show any marked decrease as the spawning season advances in the same stage of maturity. Whenever there is any decline, it is related to advancement of maturity. While the ratios between different size groups of ova are within comparable limits for 1959 to 1962, the number of immature oocytes is very high and of mature ova low for 1963 material. No marked differences is noticed in the ratios between virgin spawners and recovering spawners.

The spawning season is found to be of short duration extending normally from July to September with intensity of spawning during July to August.

There is distinct acceleration of growth rate in the spawners during the spawning season and the increment is greater in virgin spawners compared to recovering ones.

The records clearly indicate that the oil-sardine normally enter the spawning season twice in their life time. This feature and other findings on spawning season and size at sexual maturity are discussed with the observations of earlier workers on the same fish.

The probable spawning area of oil-sardine is also indicated.

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