SPAWNING BEHAVIOUR AND FECUNDITY OF THE INDIAN MACKEREL, *RASTRELLIGER KANAGURTA* (CUVIER), AT MANGALORE

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The earliest reference to the fecundity of the Indian mackerel was by Devanesan and John (1940) who estimated the number of ripe eggs in the mackerel ovary as 94,000. Subsequent work was directed mostly towards finding out the spawning behaviour of this fish, by the study of the intra-ovarian eggs. Pradhan (1956) indicated the possibility of the Indian mackerel spawning the eggs in successive batches over a prolonged period, like its Atlantic counter-part *Scomber scombrus* (L). Pradhan and Palekar (1956) described the maturity stages I to VII, based on the external appearance of the ovary, its size relative to the abdominal cavity, and the range of ova-diameter readings. However, they have not given any ova-diameter frequency polygons. Sekharan (1958) studied the ova-diameter frequency in a few ovaries of the mackerel, ranging in maturity stage from II-III to V-VI, VI-VII and a few spent ovaries. He stated that his investigation showed a possibility of the mackerel eggs ripening in batches and of their release in succession. Radhakrishnan (1962), adopting the method followed by Clark (1934), Prabhu (1956), and Qasim and Qayyam (1961), studied the ova-diameter frequency seasonally and indicated the possibility of the mackerel shedding its eggs in batches. Vijayaraghavan (1962) followed a different procedure. Employing very high magnification, he measured ova with diameter greater than 0.525 mm. Plotting this frequency with a small size interval (3.5μ) he claims the modes were clearly distinguishable. These modes according to him were well-defined batches of eggs ripening in succession. Rao (1962) studied the ova-diameter frequency in maturity stages I-V and VII. However, spawn-ripe ovary corresponding to stage VI, as he stated, was not obtained in his study.

Though it is generally agreed by all workers that the eggs in the mackerel ripen in batches and are released in succession, no attempt has been made so far to trace the development of the eggs from stage I to their ultimate end in stage VII, the spent condition. The frequency histograms given by Radhakrishnan (1962) have uneven outline and the author had not attempted to fit normal curves to the polymodal frequencies. He depended on the cellular structure of the ova to classify them into groups. The method followed by Vijayaraghavan (1962) to split up the normal frequency he obtained into smaller modes is of doubtful value. The size interval for

grouping biological measurement data is to be determined on some criteria. An infinitely small size interval brings out infinite number of modes and the utility of such a procedure in biological studies is not clearly indicated.

In this investigation, the development of the intra-ovarian eggs was traced from stage I to VII. Following the conventions laid down by Hickling and Rutenberg (1936) and De Jong (1939) and adopting the procedure given by Holt (1959), the number of batches and batch size were determined on the basis of ova-diameter frequency in spawning, partially spent and spent fish.

MATERIAL AND METHODS

Mackerel in very advanced stages of maturity were not easily available. This experience was shared by all workers on this aspect. But the present author could collect during 1961, 22 mackerel in various stages of spawning. The other stages of maturity (I to V) were obtained without difficulty. All material was preserved in 2% formaldehyde solution and analysed at a later date. For ova-diameter frequency the number of eggs measured was decided by the range in ova-diameter. Thus, for advanced stages more than 1,000 ova were measured from each ovary, in three samples taken from anterior, middle and posterior regions of the ovary. For the earlier stages (I and II) lesser numbers of ova were measured. The frequencies for the 3 samples from each ovary were pooled together as no significant differences were found between them.

Fecundity was estimated as follows. The entire ovary was weighed first and then a small sample piece was taken and weighed. The number of eggs in the sample piece was enumerated with the help of a counting chamber and a table of random numbers. Eggs below 0.198 mm in diameter were eliminated as they contained no yolk. The total number of eggs in the ovary were computed by the formula

$$\text{Number of eggs} = \frac{\text{Total weight of ovary X number of enumerated eggs}}{\text{Weight of enumerated eggs}}$$

All eggs with a diameter greater than 10 ocular micrometer divisions (0.198mm) were measured in the usual manner. The sample frequency was raised to the total number of eggs in the ovary to find out the relative strength of each group of ova by the following formula

$$\frac{\text{Number in the } i \text{ th group}}{\text{Number of eggs in the sample}} \text{X} \quad \text{Number of eggs in the ovary}$$

The month-wise frequency of occurrence of the different stages of maturity in mackerel measuring 210 mm and above, pooled for the period 1958-1961, is given in Table 1.

For finding out the minimum size at maturity, the maturity curve (Wallace, 1909) was plotted, considering stage I and II as immature and the rest of the stages as mature.

CLASSIFICATION OF MATERIAL

The maturity key given by Pradhan and Paleker (1956) was taken as a general basis for designating the various stages of maturity, from stage I to VIa. The differences wherever they occurred were pointed out. This key was, however, found adequate for the above stages (I to VIa) only.

Stage VIc is introduced to describe a condition of the ovary encountered for the first time (on the basis of work published so far). The following criteria were followed in classifying the ovaries in spawning condition:
1) External appearance

   a) Gross size in relation to abdominal cavity

   b) Whether bulging, half shrunk or fully shrunk

   c) Whether of plum-puding appearance or otherwise

   d) Whether yellow in appearance or blood-shot

2) Weight of the gonad

3) Range and frequency of ova-diameter readings.

DEVELOPMENT OF THE INTRA-OVARIAN EGGS

The ovary in stage I contained only minute, transparent eggs ranging in diameter from 0.039 to 0.22 mm (Fig. 1). Eggs above 0.2 mm contained a few yolk granules but all the eggs below 0.2 mm were yolkless. In stage II the ova-diameter ranged up to 0.57 mm. There was only a single mode at 0.22mm. This mode was designated as 'a' in Fig. 1. A few eggs which were becoming opaque with accumulation of yolk were present in this stage. In stage III the ova-diameter ranged up to 0.63 mm with modes at 0.46 mm, 0.34 mm and 0.22 mm, designated as 'a', 'b' and 'c' respectively. The eggs had become opaque with yolk accumulation. In stage IV, maximum ova-diameter was 0·75 mm and mode 'a' had shifted to 0.63 mm, mode 'b' to 0.46 mm and mode 'c' to 0.33 mm. The eggs in the most advanced mode were completely opaque and round with the accumulated yolk. In stage V, the maximum ova-diameter increased to 0.99 mm and mode 'a' shifted to 0.87 mm. The other two modes 'b' and 'c' remained stationary in the positions they occupied in stage IV. In this stage, the eggs were becoming transparent at the periphery. In stage VIa, the range was up to 1.05 mm, and the most advanced mode 'a' was at 0.93 mm. The other two modes 'b' and 'c' remained in the same position as in stage IV. The eggs in the most advanced mode had become transparent. Stage VIa gonad had

a pronounced 'plum pudding' appearance. Stage V resembled this stage to some extent but stage VIa could be distinguished from stage V by the more bulging and more pronounced plum pudding appearance. In stage VIb the range of ova-diameter was the same as in stage VIa. But the most advanced mode was at 0.81 mm and the mode to its left was at 0.46 mm. Another mode was present at 0.26 mm. Stage VIb had a shrunken appearance and it was blood-shot. A few transparent ova were seen on the surface. In stage VIc, a stage newly introduced here, the most advanced mode was at 0.81 mm, and to its left was a mode at 0.45 mm. Stage VIc was much shrunk and the blood-shot appearance was more pronounced. In stage VII a few opaque ova, measuring up to 0.63 mm, in a degenerate condition were found along with numerous transparent, yolkless, immature ova.

The spent ovary (stage VII) passes into the spent-recovering phase, referred to as stage IIa in Table 1. Ovary in stage IIa weighs less than a gram and its two lobes show slight asymmetry both in length and width. Most of the larger-sized residual eggs of stage VII were absorbed and the blood-shot appearance almost disappeared. This stage can be recognized by the presence of a few opaque eggs measuring up to 0.3 mm, scattered in the midst of numerous small transparent eggs and by the presence of oil-droplets in smear preparation, as in the case of spent gonads. However, it has no empty lumen as in the case of the spent gonad and is smoother in external appearance.

OVARIES OF THE SPAWNING MACKEREL

Weight groups

The length of spawning mackerel ranged from 220 to 238 mm, and the weight from 121 to 151 g (Table 2). The weight of the gonad ranged from 1.95 g to 16.82 g and based on weight the gonads can be grouped into three classes (Table 3). The full gonads were in the weight range of 14.70-16.82 g, the next group (partially spent) were in the range of 5.32-11.20 g and the last (almost spent) 1.95-5.64 g. The average weight was 15.8 g, 8.2 g and 3.8 g respectively. These three classes of ovaries could be distinguished from other stages even from external appearance. The partially spent ovaries (VIb) have the same weight as stage V ovaries but the two have distinct differences in appearance. Stage V is yellow in colour and round, whereas VIb is blood-shot and partly shrunk. Similarly, stage VIc ovaries, though they fall in the weight-range normally met with in maturing stages II-III, could be distinguished by their blood-shot and much shrunken appearance.

Ova-diameter frequency in the spawning mackerel

The ova-diameter frequency in the full (VIa), partially spent (VIb) and almost spent (VIc) ovaries of the mackerel are shown in Fig. 2. The length of the fish and the weight of the gonad are indicated above each frequency curve. Fig. 2 (1), (2) and (3) correspond to stage V where the first batch of eggs (mode 'a') was ripening. The modal size was 0.81 mm, 0.74 mm, and 0.87 mm respectively. In the same figure,

		210—19 mm			220—29 mm						230—39 mm							240—49 mm						250—59 mm						
		II	III	IV	II	III	IV	V	VI	VII	II	III	IV	V	VI	VII	IIa	II	III	IV	V	VI	VII	IIa	II	III	IV	V	VII	IIa
January	E	27	2		25	4					5							3						6						
	M	61			20						2																			
February	E	14	7		19	5					1	1			2	8		2	2				5	5	1	1			6	14
	M	37	12	1	23						2							2	2											
March	E	1			3		3				5	4	2			2	9	5	3		1	8	1	3			2			
	M	19	12	4	20	6	16				7	4				3		1				1								
April	E																													2
	M		16	6	14	8					3																			
May	E																							2	2					
	M		12	8	6	17	1				1											1		2				1		
June	E																													
	M		1	5	1	6	1				5																			
July	E																													
	M			4	22	4					18	2				2	3	2						3						
August	E																													
	M			8	12	3	4				7	6	1											1						
September	E																													
	M			2	19	10					1	13	2						1											
October	E																													
	M	26		9	6		12	11	2		8	8		2	2							3								
November	E																													
	M	51	1		13						1					1	2					1	2							
December	E	4	4		4																									
	M	88			36																									

Note: E-Estuarine; M-Marine.

Frequency of occurrence in size group 260-269 mm: February - E. II-1, VII-1 & IIa-1; March - E. VII-2; July - M. V-1;
Size group 270–279 mm: March - E. III-1; VII-1.

TABLE 2. *Details of material studied in the investigation on the spawning behaviour and fecundity of the mackerel.*

Sl. No.	Length of fish in mm	Weight of fish g a	b	Weight of gonad g	Condition factor a	b	Fecundity	Remarks
1.	238	138	128	9.925	0.0079	0.0073	1,04856	Stage V
2.	234	148	114	9.06	0.0116	0.0109	1,03859	-do-
3.	228	149	131	8.05	0.0125	0.0119	1,07868	-do-
4.	231	131	115	15.902	0.0106	0.0093	1,10420	Stage VI
5.	228	142	125.2	16.82	0.0119	0.0106	1,23000	-do-
6.	232	146	130.1	15.85	0.0117	0.0104	1,11000	-do-
7.	232	138	123.4	14.66	0.0111	0.0098	1,04899	-do-
8.	226	123	115.8	7.2	0.0107	0.0100	77,250	Partially spent
9.	230	121	112.4	9.4	0.0114	0.0106	73,763	-do-
10.	230	141	129.8	11.2	0.0116	0.0107	72,146	-do-
11.	220	130	122.5	7.57	0.0122	0.0115	61,187	-do-
12.	226	132	123	9.05	0.0114	0.0107	76,831	-do-
13.	227	134	125.6	8.45	0.0115	0.0107	93,151	-do-
14.	226	129	120.5	8.49	0.0112	0.0105	70,183	-do-
15.	228	135	125.9	9.18	0.0114	0.0106	82,187	-do-
16.	227	131	124.9	6.12	0.0112	0.0107	76,975	-do-
17.	224	131	125.7	5.32	0.0117	0.0112	67,627	-do-
18.	228	125	122.1	2.91	0.0106	0.0103	29,974	Almost spent
19.	228	142	136.8	5.18	0.0120	0.0115	32,116	-do-
20.	228	138	136	1.95	0.0116	0.0115	20,911	-do
21.	227	151	127.6	3.36	0.0129	0.0126	42,337	-do-
22.	223	141	135.4	5.64	0.0127	0.0122	46,585	-do-

a- with gonad, b- without gonad

curves (4)-(7) represent full ovaries (VIa) where more eggs were seen in batch 'a'. Fig. 2 (4) was less advanced than the other three. The modal size in Fig. 2 (4) was 0.87 mm and in the other three it was 0.93 mm. Panels (9)-(17) in the same figure represent partially spent gonads (VIb). Here the most advanced mode in contrast to VIa was of much smaller dimensions. In six of these ovaries the most advanced mode was at 0.81 mm, in three it was at 0.87 mm and in one it was at 0.93 mm, i.e., the same size as that of mode 'a' in the full gonad (stage VIa). In other words, the curves in panels (9)-(17) probably indicate the progression of mode 'b' to the stage of shedding. Panels (18)-(22) represent almost spent gonads. In four out of five of these ovaries, there were only two modes, in contrast to the three modes seen in all the previous stages. The most advanced mode was at 0.81 mm and the one to its left was at 0.46 mm.

TABLE 3. *Description of the ovary of the mackerel in different phases of spawning.*

Stage of ovary	Position of most advanced mode	Weight of gonad (in grams)		Total Number of mature eggs (in thousands)		Number of unripe eggs (in thousands)		Number of ripe eggs (in thousands)		External appearance
		Range	Average	Range	Average	Range	Average	Range	Average	
V	0.75-0.87 mm	8.05-9.93	8.68	105-108	106	74-101	80	7-30	22	Occupying full length of body cavity; Yellowish in colour; Plum-pudding appearance present.
VIa	0.87-0.93 mm	14.66-16.82	15.8	105-124	110	61-78	68	33-55	45	Bulging; Abdominal region of the fish bulges out markedly. Yellowish in colour; Plum-pudding appearance marked.
VIb	0.81-0.93 mm	5.32-11.2	8.2	61-93	75	44-72	57	13-29	18	Partly shrunk; About the size of stage V ovary but wrinkled and blood-shot in appearance.
VIc.	0.81 mm	1.95-5.64	3.2	21-46	34	16-33	26	5-13	9	Much shrunk; Fills only half; the abdominal cavity; Blood shot;

TABLE 4. *Ova-diameter in the most advanced mode, in mackerel ovary of different stages of maturity as observed by various authors.*

Investigation stages	Pradhan & Palekar (1956)	Sekharan (1958) Range up to	Mode	Radhakrishnan (1962) Range up to	Mode	Present Investigation Range up to	Mode	Vijayaraghavan (1962) Range up to	Mode	Narayana Rao (1962) Range up to	Mode
I	0.046-0.27			0.204	Not indicated	0.215	—	—	—	0.20	0.15
II	0. 28-0.37	0.12	0.045			0.57	0.22	—	—	0.30	0.15
III	0. 37-0.46	0.12	0.06	0.30	0.255-0.272	0.63	0.46	—	—	0.50	0.40
IV	0. 46-0.56	—	—	0.510 0.646	0.323-0.510 0.629-0.646	0.74	0.63	—	—	0.60	0.50
V	0.'57-0.81	0.645 0.675	0.490 0.490	0.850 0.74	0.629-0.749 0.629-0.714	0.98	0.87	—	—	0.7	0.6
VI	0. 57-0.81					1.05	0.93	0.73	0.672	—	—

Note: Measurements in mm

Spawning and batch size

The total number of maturing (yolked) eggs in the full gonads (Stage VIa) ranged from 105 to 124 thousand with an average of 110 thousand. In the partially
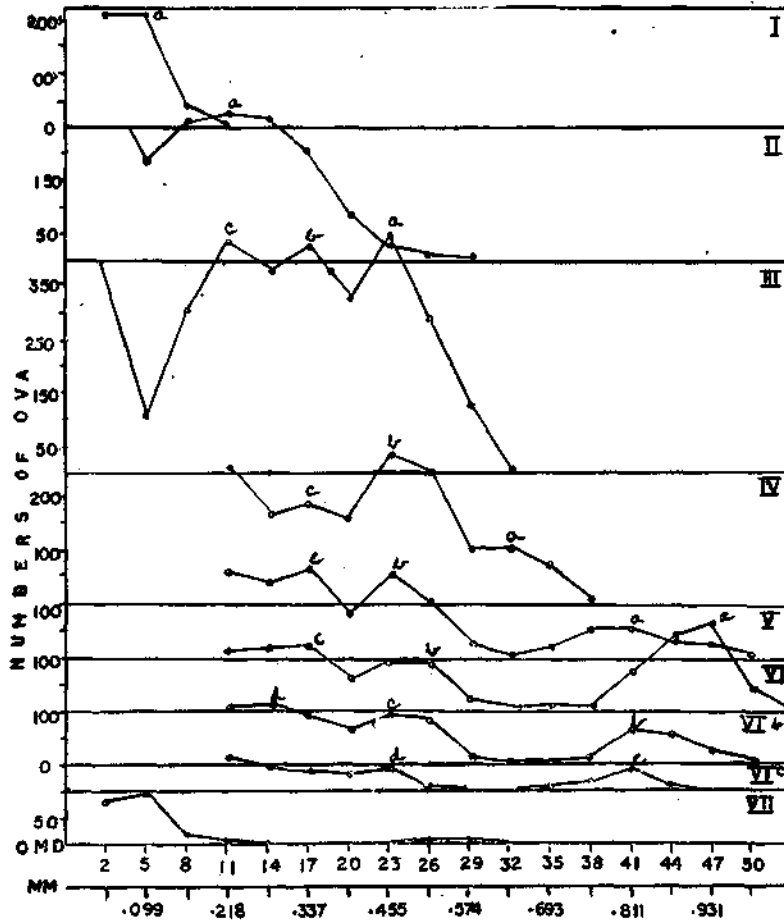
FIG. 1. Ova-diameter frequency in the mackerel ovary of different maturity stages.
O.M.D.—ocular micrometer divisions; MM-millimeters.

spent gonads (VIb) the total number of eggs ranged from 61 to 93 thousand with an average of 75 thousand. In the almost spent gonads (VIc) the range was from 21 to 46 thousand, with an average of 34 thousand.

In stage VIa three distinct modes were observed, as mentioned already. The most advanced mode designated as 'a' represents the first batch of eggs, the preceding group 'b' represents second batch and the group of eggs 'c' to the extreme left represents the third batch.

The estimated number of eggs in the three batches 'a', 'b' and 'c' of stage VIa are given below (based on four ovaries of mackerel in the size range 228-232mm).

(Counts in thousands)

	a	b	c	Total
Range	33-55	24-33	30-45	105-124
Average	45	29	38	110

If the number in each batch is successively deducted from the total average number, the number resulting from it will fall in the range of partially spent and almost spent gonads. Thus with the first batch (a) average of 45 thousand deducted from 110 thousand (average number of eggs in stage VIa) the resulting number, 65 thousand, falls in the range for partially spent gonads (VIb), 61 to 93 thousand.
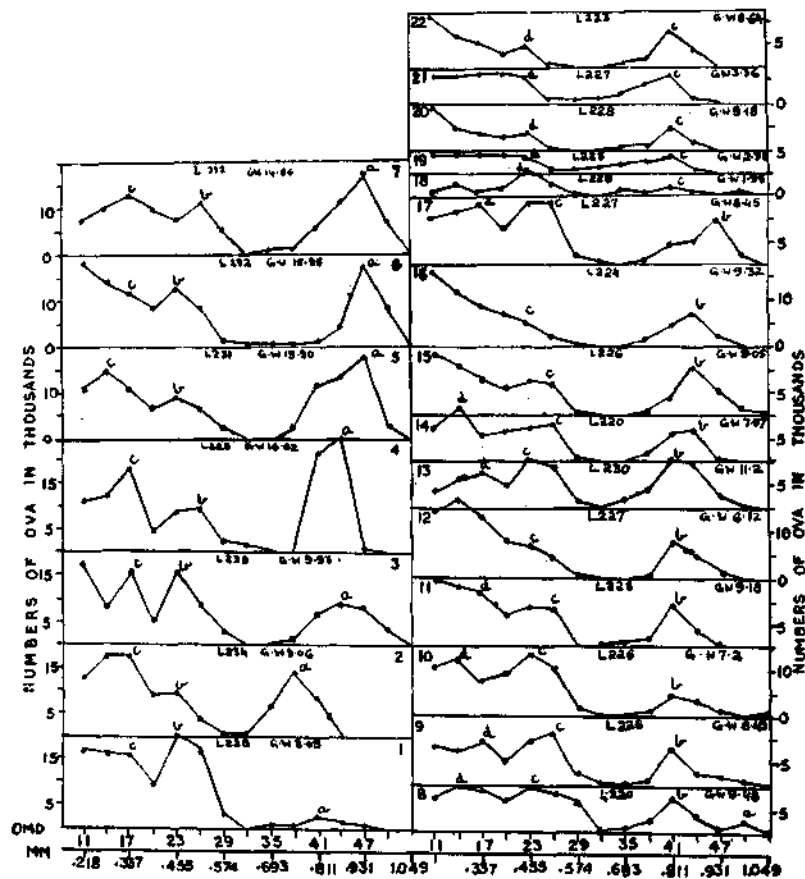
FIG. 2. Ova-diameter frequency in spawning mackerel. O.M.D.— ocular micrometer division: MM-millimeters.

Similarly, with the second batch removed (65,000-29,000) the resulting number, 36 thousand, falls in the range for "almost spent" gonads (VIc)—21 to 46 thousand. The batch size of 'a' and 'b' seen in stage VIa might approximately represent the actual number of eggs released in the first (a) and second (b) batches, but for the third batch (c), correction has to be applied as some eggs were found in degenerating condition in the completely spent ovary.

It might be of interest to add here that stage V ovaries contained as many mature eggs as stage VIa ovaries though the weight of the former was about half of the latter. The modes in stage V are not as advanced as in VIa.

Spawning

In Table 1, the frequency of occurrence of the different maturity stages in mackerel measuring 210 mm and above, is given. Data for material obtained from the marine and estuarine environments are shown separately. Earlier, George *et al.* (1959) recorded the occurrence of partially spent, spent and recovering stages from the Netravati estuary, near Mangalore.

Mackerel in maturity stage IV and above were observed from February to October, though peak numbers were observed during the period May to October only. The October material contained mackerel in stage V in fairly good numbers and there is every probability that these mackerel spawn in subsequent months. Spent and spent-recovering mackerel were observed along with some mackerel which have reached stage IV of maturity, in the estuarine material, during the period January to March.

As mackerel in ripe condition are rare in near-shore catches, it may be presumed that the spawning grounds are beyond the present fishing limits. The mackerel fishery is extremely poor or totally absent during the period, June to September. The near-shore fishery declines rapidly and comes to a close much earlier. During the January-May period gill nets land catches of mackerel. Rao *et al.* (1962) made the observation that fishermen extend the area of operation of *kanthabale* (a bottom drift gill net) from 6 to 15 fathoms, as the season advances. These facts indicate that the mackerel move away from near-shore waters as they advance in maturity condition. But spent and spent-recovering stages were recorded in near-shore waters and the October material which contained spawn-ripe mackerel was also collected from in-shore catches. This may indicate that the spawning grounds cannot be very far off from the area fished at present.

DISCUSSION

The study of the development of the intra-ovarian eggs (Fig. 1) has shown that the developing eggs segregated into three groups (a, b and c) by the time the ovary reached stage III. These three groups persisted in subsequent stages also, which indicates that the ova are perhaps shed in three batches. This view gets support from

the detailed studies made on ovaries of mackerel in different stages of spawning. As has already been shown before, the ovaries of spawning mackerel also fall into three classes with reference to their external appearance, total weight, ova-diameter frequency and the number of ova (Table 3). After the most advanced batch 'a' is shed the ovary loses about half its weight; a corresponding decrease is also seen in the total number of eggs. During subsequent development, batch 'b' also disappears like 'a', the ovary losing again half its weight during the process; the total number of eggs also decreases correspondingly. The material studied in this investigation clearly shows the growth of batch 'a' and 'b' to 0.93 mm, probably the size at which eggs are shed. However, the maximum modal size of 'c' observed was only 0.81 mm. but the eggs in this batch also probably grow further and are shed. If the time lag between the release of batches is considerable, three well-demarcated broods can be expected in an year. That three broods are possible in an year class has been indicated earlier by Rao *et al.* (1962) on the basis of length frequency studies on this fish.

In stage V the total number of eggs, as shown already, was equal to the total number of eggs in stage VIa, but the numbers in the ripe and unripe groups were different. In stage V, the number of ripe eggs was 22 thousand on the average and in stage VIa it was 45 thousand, which indicates that some eggs from batch 'b' were added on to batch 'a'. But the majority of eggs in batch 'b' do not apparently grow at the same time, which explains its retaining identity even in stage VIa.

Stage VIa, where batch 'a' eggs had developed to the full, is the stage where 'batch strength' can be assessed with reasonable accuracy. The assumption that ova in the most advanced batch will be spawned at a given time is generally made by workers on fecundity (Mac Gregor, 1957). Based on this assumption the number of eggs in the most advanced group represent the number of ova released in the first batch. After the first batch is shed the subsequent batches develop. The small number of ripe eggs in VIb shows clearly that almost or the entire group of eggs in batch 'a' are shed. Since batch 'b' only can ripen after batch 'a', the numerical size of batch 'b', as seen in VIa, might approximately represent the number of eggs shed in the second batch. For the third batch or batch 'c', however, correction has to be applied as some degenerating eggs were found in the completely spent stage. The reduction in the total number of developing eggs of all groups from stage VIa to VIb and VIb to VIc shows that the assumptions made above regarding the batch size based on VIa, are tenable. The average estimated number of each batch of eggs in stage VIa, deducted successively from the total estimated average number in VIa, resulted in a number which fell within the range of observed number of mature eggs in partially spent (VIb) and almost spent (VIc) ovaries.

The range of ova-diameter, the maximum and modal size of ova in the most advanced group, observed in the advanced stages of ovaries in the present investigation were greater than that observed by all previous workers. The earliest maturity

key was that given by Pradhan and Palekar (1956). Stages I to V of this key follow the maturity scale adopted by the International Council for the Exploration of the Sea in the herring scheme (Holt, 1959). Sekharan (1958) and Radhakrishnan (1962) followed the same conventions laid down by the ICES. In Table 4 the ova sizes observed so far by all the workers including the present author are given. Stage III of the present investigation corresponds to early stage IV (May specimens) of Radhakrishnan (1962) and stage IV of Pradhan and Palekar (1956). The late stage IV of Radhakrishnan (1962) is about equal to stage IV given here. In stage V there is broad agreement except that the maximum size of ova observed in the present investigation is larger. In stage VI (VI a of Pradhan and Palekar and the present author), as already mentioned, the total range, maximum and modal size of ova in the most advanced group are greater in the present investigation. Radhakrishnan (1962) stated, "The maximum size of intra-ovarian eggs noted at Karwar is 0.935 mm and probably the ripe ova may be slightly larger than the size mentioned above". The maximum size of ova observed in stage V ovary in the present investigation was 0.99 mm. However, Radhakrishnan (1962) recognized 4 groups of ova in the advanced stage of ovary, the immature, maturing, mature and ripe. The immature ova were ignored in this investigation from stage IV onward and the remaining three groups of ova correspond to the other three groups mentioned by him. Rao (1962) stated that no spawn-ripe ovary corresponding to stage VI was obtained during his study. The other stages studied by him (I-V and VII) correspond to the stages given in the key by Pradhan and Palekar (1956). Vijayaraghavan (1962) studied ovaries in V-VIa stages of maturity, and he observed two modes, one at 0.288 mm and another at 0.672 mm in the maturing group of ova. He considers the size of ova observed by him in the most advanced mode rather small compared to the range given by Pradhan and Palekar (1956) for VIa ovaries. The advanced maturity stages (V-VI) studied by Sekharan (1958) correspond to stage IV of other workers on the basis of maximum ova-diameter. The modal size in the most advanced group observed by him was only 0.49 mm. The appearance resembling the plum-pudding stage described by him and shown in a photograph was caused, according to him, by translucent ova and not by transparent ova.

Considering the wide range in the modal size of the most advanced group of ova observed by various authors in what was considered to be stage VI ovaries, from the minimum of 0.49 mm, as given by Sekharan(1958), to the maximum of 0.93 mm as observed in this investigation, one is led to the inevitable conclusion that all these might not be stage VIa ovaries. As such a wide range in the modal size of ova in the most advanced mode is not expected, particularly when the range in length of the fish is not considerable[1]. The stage was not mentioned specifically by some authors

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[1] Beverton and Holt (1957) state "......egg size within most marine fish seems remarkably constant, though the instance of departure from a proportional fecundity—weight relationship thorough variation in egg size in a marine fish appears to be provided by the work of Hagerman (1952) on the Pacific Dover sole *Microstomus pacificus*, Lockington."

but the probable range such as V-VI or IV-VI was given. If information regarding the weight of the ovary, external appearance, and its size relative to abdominal cavity was given individually for each stage, it would have facilitated better comparison.

Earlier workers have indicated the spawning season of this fish as from March to September. In the present investigation, advanced stages of maturity (stage IV and above) were observed from February to October. In October mackerel in stage V were observed in fairly good numbers and these might spawn in subsequent months. Spent and spent-recovering stages along with stage IV were found during the January-March period. However, mackerel in advanced stages were observed in appreciable numbers in the period May-October. The Indian mackerel might be spawning throughout the year though there might be peaks in its spawning activity.

That the spawning grounds are beyond the present fishing limits is apparent. During the January-May period the fishery moves away from shore as the season advances. During June-September the catches are sporadic, but the majority of the mackerel in the catches are in advanced stages of maturity. However, spent and spent-recovering stages were recorded from near-shore waters. In October 1961 even mackerel in running condition were obtained from the inshore area. This shows that the spawning grounds cannot be very far away from the area fished at present.

Mackerel caught in the estuary were larger in size than those caught in the marine environment. In the Atlantic mackerel schooling takes place according to size (Sette, 1950). The Atlantic mackerel are known to appear in shallow inshore areas after spawning (Sette. 1950; Steven, 1948). The occurrence of spent fish in estuarine areas adjoining the shallow coastal waters and their larger size range indicate that the Indian mackerel have similar habits as the Atlantic mackerel.

SUMMARY

The development of the intra-ovarian egg was followed from stage I to VII. The maturing ova segregated into three groups by the time the ovary reached stage III and these three groups persisted in subsequent stages. The growth of the second and third batches of ova was arrested at stage IV, while the first batch ripened. Only after the first batch was released, the other two batches progressed in development.

The 'batch size' as seen in maturity stage VIa was considered as representing the number of eggs released in each batch and the reliability of this assumption was checked by comparing the total number of eggs in stage VIa, VIb and VIc.

The minimum size at maturity of the fish derived from the maturity curve was 21.7 cm.

A table of maturity stages pooled for the period 1958-61 is given. Fishes in advanced stages of maturity occurred almost throughout the year except during November-December and January.

REFERENCES

BEVERTON, R.J.H AND S.J. HOLT. 1957. *On the dynamics of exploited fish populations.* Her Majesty's Stationery Office, London.

CLARK, F.N. 1934. Maturity of California sardine *Sardina caerules*, determined by ova-diameter measurements. *Calif. Div. Fish and Game, Bull.*, 42: 1-49.

DE JONG, J.K. 1939. A preliminary investigation on the spawning habits of some fishes of Java Sea. *Treubia*, 17: 307-327.

DEVANESAN, D.W. AND V. JOHN. 1940. On the natural history of *Rastrelliger kanagurta* (Russel) with special reference to its spawning season and eggs. *Curr. Sci.*, 9: 462-464.

GEORGE, P.C., M.H. DHULKHED AND V. RAMAMOHANA RAO. 1959. Observations on the mackerel fishery of the Netravati Estuary, West Coast, South India. *J. Bombay nat. Hist. Soc.*, 56 (1): 32-38.

HAGERMAN, F.B. 1952. The biology of the Dover sole *Microstomus pacificus*, (Lockington). *Calif. Dept. Fish and Game, Fish. Bull.*, No. 85.

HICKLING, C.F. AND E. RUTENBERG. 1936. The ovary as an indicator of spawning period of fishes *J. Mar. biol. Ass. U. K.*, 21: 311-317.

HOLT, S.J. 1959. Report of the International Training Centre on the Methodology and Techniques of Research on Mackerel (*Rastrelliger*). *Report No.* 1095 *F. A. O. Rome.*

MAC GREGOR, J.S. 1957. Fecundity of the Pacific sardine (*Sardinops caerulia*). *Fish. Bull., U. S.*, 50 (121): 427-468.

PRABHU, M.S. 1956. Maturation of intra-ovarian eggs and spawning periodicities in some fishes. *Indian J. Fish.*, 3 (1): 59-90.

PRADHAN, L.B. 1956. Mackerel flishery at Karwar. *Indian J. Fish.*, 3 (1): 141-185.

PRADHAN, L.B. AND V.C. PALEKAR. 1956. Key to the stages of sexual maturity of *Rastrelliger kanagurta* (C). *Indian J. Fish.*, 3(1): Appendix I.

QASIM, S.Z. AND A. QAYYAM. 1961. Spawning frequencies and breeding seasons of some fresh water fishes with special reference to those occurring in the plains of Northern India. *Indian J. Fish.*, 8 (1): 24-43.

RADHAKRISHNAN, N. 1962. Observations on the maturity and spawning of Indian mackerel *Rastrelliger kanagurta* (Cuvier) at Karwar. *Indian J. Fish.*, 9 (2): 512-523.

RAO, K.V. NARAYANA 1962. Observations on the bionomics of the Indian mackerel *Rastrelliger kanagurta* (C) caught in the Lawsons Bay, near Waltair, Andhra Coast. *Proc. Symposium on Scombroid Fishes.* Part I. Mar. biol Assoc. India.

RAO, V. RAMAMOHANA, K. V. SEKHARAN AND M.J. PRADHAN. 1962. On the mackerel fishery of the Mangalore area during the period 1957-'61. *Indian J. Fish.*, 9 (2)A : 653-678.

SEKHARAN, K.V. 1958. On the south Kanara coastal fishery for mackerel *Rastrelliger kanagurta* (Cuvier), together with notes on the biology of the fish. *Indian J. Fish.*, 5 (1): 1-31.

SETTE, O.E. 1950. Biology of the Atlantic mackerel (*Scomber scombrus*) of North America-II-Migrations and habits. *Fish. Bull.*, *U.S.*, 49.

STEVEN, G.A. 1948. Contribution to the biology of the mackerel *Scomber scombrus* L. Mackere migrations in the English Channel and Celtic Sea. *J. Mar. biol. Ass. U. K.*, 27: 517-539.

VIJAYARAGHAVAN, P. 1962. Some observations on the spawning behaviour of the mackerel *Indian J. Fish.*, 9 (2): 647-652.

WALLACE, W. 1909. Report on the size and age of plaice at maturity in the North Sea and English Channel. *Mar. Biol. Assoc. U.K. Internat. Fishery Invest.*, 2nd Report Southern area Part II: 51-88.