THE PROBLEM OF AGE-DETERMINATION IN THE INDIAN MACKEREL, *RASTRELLIGER KANAGURTA*, BY MEANS OF SCALES AND OTOLITHS

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ABSTRACT

The study of the scales of *Rastrelliger kanagurta* (Cuvier) collected from different centres during the period 1955-67 and 1969-70 showed that at all centres specimens below 21 cm in total length were without scale-rings; a small percentage of specimens in the 21-22.9 cm group showed rings, while a large percentage among those above 23 cm total length showed the rings in all the centres, this percentage being the smallest (63.1%) at Calicut and largest (94.3%) at Karwar. Two rings occurred frequently in specimens above 25 cm and up to four rings occurred in the very large specimens of Vizhinjam and Mandapam, but in these large specimens reading of the rings was difficult as they frequently became faint and obscured as a result of the thickening of the scales subsequent to the ring-formation. The scale-rings seem to be formed as a result of a physiological strain on the fish during the process of growth and ripening of the gonads and also spawning. When clear rings were not noticed in mackerel with gonads in advanced stages, there were thin margins, which indicated the beginning of ring formation. The otoliths did not show any annuli that could be used for age-determination.

It is suggested that the mackerel reaches a total length of 11-15 cm by the end of the first year, 21-24 cm by the end of the second year, 25-27 cm by the end of the third year, and 28-29 cm by the end of the fourth year of life.

INTRODUCTION

The question of assessing the exact age of the Indian mackerel at any given size has always been a difficult one to answer; consequently the determination of the rate of growth during the different phases of its life has also been, to some extent, an unsolved problem. Holt (1959) has given a summary of the growth data available for some scombroids and indicated an approximate value for the factor k ("catabolic growth coefficient") for *Rastrelliger*.

In the case of the Indian mackerel (*Rastrelliger kanagurta*) studies on the length-frequencies during different seasons have led to certain conclusions which have found general acceptance in the light of the existing knowledge about the biological and fishery trends during different months and years at the various regions along

the coast. Pradhan (1956) may be said to be the first published study of any clear evidence regarding the length-frequency trends continuously over a number of years, these giving some clues, though in a gross way, as to the age and growth of the species during different seasons at Karwar. According to this work the species reaches (at Karwar) a total length of 10 cm at the end of the first year of life and 21-23 cm at the end of the 2nd year; the fish is about two years old when it spawns for the first time. After a detailed examination of available data along with data specially collected at Malpe on the west coast, Sekharan (1958) came to conclusions similar to the above. According to him the mackerel of 12-15 cm total length may be one year old, the two-year old fish reaching a size of 21-23 cm. Narayana Rao (1962) found that on the east coast the mackerel grew to 15-16 cm total length in 7-8 months. Virabhadra Rao (1962) has reviewed the length-frequency data for both the east and west coasts with special reference to the spawning season and the occurrence of juveniles and his views are in conformity with those of Sekharan. Radhakrishnan (1967) has reviewed the length-frequency trends at Karwar for some years.

Pradhan (1956) did not find any growth-rings in the scales of the Indian mackerel. George and others (1959) have found rings in the scales of the large mackerel which they collected in the Netravati estuary near Mangalore.

In 1958, the present author, reporting on the occurrence of growth-rings in the scales of the species, concluded that the rings were spawning marks and might prove useful in age, growth, maturity and even raciation studies (Seshappa, 1958).

Subsequently he has examined a large number of mackerel scales from different parts of the coast (but mainly from the west coast where the species is important at present) during different months and years, and the results of these studies form the material for the present paper. Otoliths were also examined from over 228 specimens of different sizes.

Material and Methods

The scale material used in the present work was partly collected by the author himself and partly sent by mackerel-scientists of the Central Marine Fisheries Research Institute from other centres along with the relevant measurements and certain biological data such as the sex and maturity stages collected during their own routine work on the species. It was not possible to take any fixed number of individuals or samples every month or season as the material had to be used strictly according to availability. It was also not possible to examine equally large numbers in all the size-groups as the smallest and largest specimens were available only occasionally. The sizes most dominant in the fishery were well represented in the studies and an effort was made to get as many of the largest and smallest sizes as possible wherever the author himself made the collections. The samples dealt with (being pooled from

different centres and seasons) do not represent random samples of the stock as far as the length-frequencies are concerned, but in other respects they can be treated as random samples.

Scales were cleaned and preserved dry partly in specially prepared covers with menthol as preservative, and partly as dry mounts between slides. Some preparations were also made using gum-chloral, gum-syrup and other mounting media; a good number of scales were preserved wet, in a mixture of equal parts of distilled water, glycerine and absolute alcohol; a formula of two parts of absolute alcohol to one part each of glycerine and distilled water proved to be better for the preservation.

The collection of the otoliths in the mackerel was made by making a longitudinal vertical slit along the middle line of the skull. The otoliths are best collected in fresh specimens; in preserved material they become too opaque and also show a tendency to break too readily. Otoliths were preserved dry after cleaning; they were not sectioned or ground.

Description of Scales

The scales of *R. kanagurta* are of the ctenoid type. The shape and size of the scales differ slightly in the different regions of the body and recently Isarankura and Naiyanetr (1964) have shown that in *R. neglectus* from Thailand the scales are first formed below the pectoral region immediately behind the operculum and last on the antero-dorsal aspect below the base of the dorsal fin. The sequence of scale-formation seems to be the same in our mackerel also in which the largest scales are actually found immediately behind the operculum and are nearly circular with a more or less central focus or starting point. The scales used for routine observations in this work were taken just below and behind the pectoral fin, always in the same area, the scales of the left side being taken normally; but scales of the right side or both sides were also considered wherever found necessary. As a rule no differences were observed in the scale-size and structure between the two sides, provided the material was strictly from the usual 'patch' stated above.

A normal, that is, unregenerated and undamaged scale has an unsculptured or smooth lower surface and sculptured upper surface. The ctenii or teeth are situated at the posterior aspect and these usually take the form of flattened and obtusely pointed structures projecting backwards. These are frequently absent in the smaller specimens. The anterior side of the scale which is imbedded in the scale-pocket is broadest in the patch under the pectoral fin. The two sides are normally shorter than the anterior and posterior margins and the whole scale thus gives the appearance of a quadrilateral with smooth rounded angles. The sculpturing on the upper side consists of a number of calcareous lines or 'sclerites' arranged around a central elliptical area known as the focus or nucleus and extending in smooth arcs from one side of the scale to the other. When there are no growth-rings, the sclerites

reach right up to the margin of the scale and also present a more or less uniform thickness, spacing and general pattern throughout their extent. In a scale with one ring, the sclerites stop suddenly after reaching a certain point and a new series starts again in a line to extend up to the edge of the scale. The gap thus left between the long inner series and the short peripheral series of sclerites is the actual growth-ring. This break may be quite prominent, or very narrow and just noticeable as a thin line, the extent of the formation depending obviously on the degree of intensity of the factor responsible for the formation of the ring itself. The check extends conspicuoulsy along the sides and the antero-lateral corners, while along the anterior aspect it may not be so conspicuously seen, as here it takes the form of one or more missing or very closely placed sclerites. The ring is absent (except occasionally) along the posterior or toothed side of the scale. In all cases the fully formed growth-ring can be traced right round the scale except at the posterior aspect. Sometimes the edge of the scale is seen to be clear and free from sclerites which stop just a little away from the free margin of the scale. A thin margin is thus noticeable; this is usually the beginning of the formation of a growth-ring.

Abnormal scales may be frequently noticed and the most common type noticed is the regenerated scale. The pattern of sculpturing, the position of the focus and other details will be out of shape in such scales. Very prominent checks can appear in the scales as re-growth starts after mutilation but it is only very rarely that these will present problems of confusion with the usual growth-rings.

Description of Otoliths

Chidambaram and Krishnamurthy (1951) studied the otoliths of the Indian mackerel and, while noticing the presence of some "rings", found that it was too difficult to read their number in the otoliths of specimens 20 cm and above in length. The present author examined the otoliths of over 220 individuals of both sexes and was not able to find any definite growth marks that could be used for age-determination. The following description based on this examination is given as the structure and appearance of the otoliths may sometimes give the impression of there being some growth rings or annuli.

The otolith (Sagitta) of the mackerel is roughly a flattened plate bent slightly in an arch, the posterior end being broad and the anterior end narrow with a pointed projecting process. The dorsal aspect of the plate is convex and along this is an open longitudinal canal (the acoustic canal), somewhat narrow in the middle but widening out at both ends. The ventral aspect of the otolith has no such canal. Closely placed and roughly concentric (and largely irregular) growth-lines mark the pattern of accretion of material during the growth of the otolith both on the dorsal and on the ventral surfaces. These lines may, however, not be noticeable inside the acoustic canal; when lines are present inside this canal, these and the lines outside the canal may be set at different angles and in different patterns. The number of these growth-lines does not seem to show any constancy at any given size. Careful

examination has revealed that these are in a way comparable to the circuli of the scales and not with any growth-rings; hence they cannot be used as age-indicators. Normally, the "annuli" in otoliths (where they occur) are marked by transparent and opaque areas which are clear when the otoliths are examined by transmitted light or even reflected light, without the need for any sectioning. In the mackerel otoliths, occasionally a false impression of a translucent zone is possible due to the presence of an accessory canal next to the acoustic canal but it is limited in extent, and careful examination under transmitted light will easily reveal the true nature of the apparent translucent area. True growth-zones in otoliths must usually extend right round the otoliths and depend not on variations in the thickness of the structure but on the natural transparency or opacity of the material forming the different regions of the otolith.

Results of Examination of the Scales

The details of the occurrence of growth-rings in scales of the Indian mackerel are summarised in Tables 1-5.

TABLE 1. *Summary of data on the occurrence of growth-rings in* R. kanagurta *from different centres*

Centre of collection	No. of fish examined	Scales with rings		Scales without rings	
		No. of fish	Length range (cm)	No. of fish	Length range (cm)
West Coast					
Karwar	705 (317)	270 (149)	22.4-26.7	435	13.2-24.3
Mangalore	120	66 (50)	22.0-27.0	54 (35)	21.1-25.5
Calicut	773 (274)	56	21.4-25.4	717	10.8-24.5
Ratnagiri	161	34	23.6-25.6	127	15.1-22.9
Cannanore/ Tellicherry	29	—	—	29	19.6-22.4
Cochin	82	4	22.0-25.2	78	19.7-23.7
Vizhinjam	72 (23)	45	22.9-29.4	27	19.5-24.3
East coast					
Porto Novo	36	3	22.0-25.0	33	—
Waltair	12	7	—	5	21.7-24.3
Mandapam	206	28	21.8-31.2	178	14.7-24.4

Note: Nos. of females examined are given in parentheses.

A feature that is common to all the centres as can be seen from Table 1 is the occurrence of rings in the higher size-ranges and their complete absence in the lower size-ranges, with a natural tendency for the two ranges to overlap in the intermediate group. This is so for the various years in which the material was collected. While the presence or absence of rings is quite clearly determined in most cases, there are occasionally specimens of large sizes with the rings not quite apparent though

normally expected to be quite clear (and *vice versa*). It is such instances which cause much of the overlap between the size-ranges of the occurrence and non-occurrence of these growth-rings.

At all the centres specimens below 21 cm were without growth-rings during all the years, irrespective of the period of capture. In the 21-22.9 cm group the specimens with scale-rings formed around 1.3% of the examined specimens at Ratnagiri, 8.4% at Karwar, 30.8% at Mangalore, 4.1% at Calicut and 8.8% at Cochin (Ernakulam) and southern centres including Vizhinjam. In the groups of 23 cm and over, the percentage of specimens with scale-rings suddenly increases though naturally there are differences among the different centres in the percentage figures. The least percentage of 63.1% occurs at Calicut while the highest percentage figure (94.3%) occurs at Karwar. Ring-formation in the southern areas seems to occur at a slightly larger average size than in the northern centres, this tendency being particularly marked at Calicut. The west coast totals show 6.7% occurrence of rings in the 21-22.9 cm group and 84.1% for the sizes of 23 cm and over.

TABLE 2. *Occurrence of growth rings in the different maturity stages of females of* Rastrelliger kanagurta (*pooled west coast data*)

	Stage II and below	Stages III and IV	Stage V and above
Total number examined	318	105	232
Number with rings	4+16*	50	142+28*
	=6.3%	=48.6%	=73.3%
Number with no rings	290+8*	1*	60+2*

Note: * Including suspected cases. Cases where the rings were not at all suspected in any way are left out in this table (for counting the number with rings).

Table 2 summarises the data on the occurrence of growth-rings in the different maturity stages of the females, taking the west coast as a whole. It is clearly seen here that the percentage figure is negligible in the first category (stage II and below); a good percentage is found in the second category (stages III and IV) and a very high percentage is found in the ripe specimens of stage V and above in maturity. This trend of occurrence is very significant and gives the clue regarding the cause of ring-formation in the scales in this species, as will be discussed later.

Table 3 shows the analysis of the occurrence of growth-rings during different months of the year in the size-group 22-24.9 cm taking the west coast data for all the years together. Table 4 shows the proportion of advanced maturity stages (stage V and above) in the total numbers of males and females examined during different months of the year from the pooled data of the west coast. Table 5 summarises the results of further observations made on the scales with special reference to the nature of the margin during the period March 1969 to December 1970, these giving further support to the general theory that will be discussed.

TABLE 3. *Occurrence of growth rings during different months of the year in* Rastrelliger kanagurta *of the size-group 22-24.9 cm considering all the years and all the centres of the west coast together*

Month of capture	Total number examined	Percentage of specimens with rings *
Jan.	70	14.3
Feb.	62	46.8
Mar.	62	62.9
Apr.	26	46.2
May	27	48.2
Jun.	77	22.1
Jul.	19	5.3
Aug.	41	41.2
Sep.	30	46.7
Oct.	152	78.3
Nov.	95	85.3
Dec.	51	3.9

* Doubtful cases are omitted in the reckoning but clearly suspected cases included.

TABLE 4. *Proportion of advanced maturity stages (stage V and above) in the total numbers of males and females examined during different months of the year (pooled west coast data)*

Months	Males		Females	
	Total No. examined	Percentage of advanced stages	Total No. examined	Percentage of advanced stages
Jan.	105	0	88	2.3
Feb.	58	22.4	64	2.8
Mar.	49	16.3	71	7.0
Apr.	39	7.7	50	12.0
May	14	14.3	23	21.7
Jun.	42	90.5	45	77.8
Jul.	3	33.3	16	50.0
Aug.	23	26.1	36	11.1
Sep.	16	18.8	18	83.3
Oct.	144	40.3	125	50.4
Nov.	161	24.2	196	26.0
Dec.	102	4.9	83	14.5

TABLE 5. *Results of scale examination in* R. kanagurta *during* 1969 *and* '70 (*Pooled results from samples of Calicut and nieghbourhood*)

Months	Total No.	Length range (cm)	Sex and maturity stages	Observation on the scales
Mar. 1969	32	19.5-22.5	13 M & 18 F, including 1 each in stage III & IV; sex not known in one	*No rings** False rings in 4
Apr.	No samples			
May	17	12.3-15.6	5 M. I, 6 F. I & 6 indeterminates	*No rings**
Jun.	10	22.7-23.9	6 F. IV & 4 M. IV	*No rings**, but *thin margin* 1 & *false check* in 1
Jul.	40	10.7-14.0 (39)	All indeterminates	*No rings**
		16.0 (1)	M. I.	*No rings**
Aug.	17	13.4-16.2 & 19.6-21.7	7 M.I., 7 F.I, & 3 indeterminates	No rings*; *false check* in one case
Sept.	68	18.2-20.4 (53)	36 M. I, 16 F. I, 1 F. II	*No rings* *; *false checks* in 6
		22.8-25.6 (15)	4 M. III-IV, 4 M. IV to VII, 1 F. IV, 6 F. VI	One with *thin margin* & all others *with one ring*
Oct.	87	19.5-21.2	42 M. & 45 F, I to II, I dominant	*No rings**, *false* checks in 8
Nov.	60	17.7-22.4	3 M. I to II, 27 F. I to II, 3 sex not known	No rings*, false checks in 9
Dec.	74	16.8-23.1	31 M, 43 F. I to II, mostly stage II	*Abnormal thin margin* in one 21.4 cm, F II, all others with *no rings, false check* in 18
Jan. 1970	102	19.1-22.6	55 M, 47 F, all I to II mostly st. II	*Abnormal thin margin* in a few scales in one specimen, 20.7 cm M. I; all others *with no rings**; false checks in 22
Feb.	25	19.9-23.2	14 M, 11 F, I to II mostly st. II	*No rings**, *false check* in 5
Mar.	No samples			
Apr.	40	20.7-22.6	21 M, 19 F, II to IV	31 with no rings* (st. II-III), 8 with *thin margin* (III-IV), abnormal thin margin in one (st. II-III) specimen
May	26	21.5-23.3 (25)	6 M, III to IV, and 18 F. III to IV, plus 1 F. II	one in *st. II* with *no rings**, all others with *thin margin* in some, most or all of the scales
		24.6(1)	F. VII	*Thin margin in formation*

Continued

TABLE 5 *Contd.*

Months	Total No.	Length range (cm)	Sex and maturity stages	Observation on the scales
Jun.	30	21.9-25.1	17 M, 13 F, III to V, moostly IV-V	"1 ring" *not clear* in 2, 25.1 cm & 25.0 cm; no ring* in 1st. III, all others with *thin margin*
Jul.	No samples			
Aug.	30	9.4-12.2 (5)	Indeterminates	No rings*
		22.8-22.5 (25)	11 M, 13 F, all in advanced stage including spent.	9 with *one ring*, all others with well-formed *thin margin*
			1, sex not known	*Thin margin*
Sep.	90	13.3-17.4 (70)	Indeterminates, I. M, and 1 F	*No rings* and no *thin margin*
		21.8-24.3 (20)	8 M, 12 F, all VI-VII	*one ring* in *some or all the scales*
Oct.	77	16.3-21.2 (76)	41 M, 35 F, all st. I to II (st. I dominant)	*No rings* and *no thin margin*
		24.2 (1)	Male stage VII	*One ring* and open margin.
Nov.	61	17.6-21.7 (60)	29 M, 31 F, all I to II stage I dominant	*No rings* and *no thin margin.*
		23.6(1)	F. VII	Thin margin present
Dec.	57	18.4-22.4	39 M. I-II	No rings & no thin margin
			27 F. I-II	No rings & no thin margin
			1 sex not seen	No rings & no thin margin

* These are also cases without thin margin.

COUNTS OF CIRCULI

In addition to the examination of growth-rings, counts of circuli were taken in a total of 427 individuals of *R. kanagurta* from the Calicut samples to check on their significance in the problem of age and growth determination. The intention was to see whether the circuli counts could give any clue to the age of the fish for use along with the data on the occurrence of growth-rings. As no rings occur in the smaller sizes of the mackerel, the need was felt to explore the available other means of checking up the age of the fish at these sizes. The average number of circuli increases with the increase in the size of the fish, but within each size-group the range is quite wide; for instance, in the 19-19.9 cm group the average number of circuli could be anywhere between 18 and 35 (Table 6).

DISCUSSION

The available data have been examined mainly from the following five points of view: (1) Are these rings comparable in appearance and details of structure to the growth-rings recognised as such in other fishes? (2) Are the rings purely

TABLE 6. *The numbers of anterior circuli in the scales of different size-groups of the Indian mackerel,* Rastrelliger kanagurta

Circuli / Total length (cm)	9-11	12-14	15-17	18-20	21-23	24-26	27-29	30-32	33-35	36-38	39-41	42-44	45-47	Total
11-11.9	3	1	—	—	—	—	—	—	—	—	—	—	—	4
12-12.9	15	2	—	—	—	—	—	—	—	—	—	—	—	17
13-13.9	11	10	1	—	—	—	—	—	—	—	—	—	—	22
14-14.9	—	5	1	1	1	—	—	—	—	—	—	—	—	8
15-15.9	—	4	7	—	—	—	—	—	—	—	—	—	—	11
16-16.9	—	3	19	16	—	—	—	—	—	—	—	—	—	38
17-17.9	—	—	10	10	3	1	—	—	—	—	—	—	—	24
18-18.9	—	—	—	6	14	5	1	—	—	—	—	—	—	26
19-19.9	—	—	—	1	15	22	3	1	1	—	—	—	—	43
20-20.9	—	—	—	—	9	27	24	14	3	—	—	—	—	77
21-21.9	—	—	—	—	5	22	35	18	10	5	1	—	—	96
22-22.9	—	—	—	—	—	3	10	7	11	1	2	—	—	34
23-23.9	—	—	—	—	—	1	—	3	4	3	1	—	—	12
24-24.9	—	—	—	—	—	—	—	1	2	4	3	1	1	12
25-25.9	—	—	—	—	—	—	—	—	—	2	1	—	—	3
Total	29	25	38	34	47	81	73	44	31	15	8	1	1	427

arbitrary in their occurrence, restricted to some centre or year, or are they regular in their occurrence in regard to seasons or size of the fish at different places and during different years? (3) If there is any regularity in the occurrence of the rings, what could be the associated factor causative to their formation, considering the fact that the tropical fishes do not show rings strictly comparable to those seen in the fishes of the temperate seas? (4) Whatever be the cause of ring-formation, could they be used in one way or the other for purposes of age-determination? (5) What use can be made of the circuli in the scales in the solution of the problem of age-determination?

It has been found that in appearance the rings seen in the Indian mackerel are closely comparable to the growth-rings described in some other fishes and particularly those described and illustrated for the Japanese mackerel, *Scomber japonicus* (=*P. japonicus*) (see Aikawa, 1937; Ouchi, 1954; Kondo, 1966 and Alagarswami, 1969).

In answer to the second question stated above, it is clear that a great deal of regularity is found in the occurrence of these rings so far as the size of the fish is concerned. No clear growth-rings have been found in specimens below 21 cm in

any of the years and at any of the centres. A certain percentage of the individuals measuring 23 cm and over show the rings in all the places, with a slight variation in the actual figures from place to place. In the Calicut material rings appeared at a slightly higher size than elsewhere, while in the Karwar material they occurred at a slightly smaller size. At all the centres, specimens above 24 cm total length have invariably shown growth-rings with only occasional cases of their absence or of difficulty of interpretation owing to faintness of the rings or their getting mixed up with false checks and abnormalities of structure. It should not also be surprising that rare instances of specimens did turn out even in the larger sizes to be without clear rings. Such exceptions usually occur almost in all species (including those in the temperate climate) but this need not vitiate the main premise (see Van Oosten, 1928). What is important is the dominant trend and that, in the present instance, seems to be quite marked and significant.

The third question relates to the utility of these rings in routine age-determination and growth-studies. Menon (1953) gives a review of the work on age-determination by scales and hard parts with special reference to tropical forms and the causative factors in the formation of the growth-rings. In the case of the Malabar sole, *Cynoglossus semifasciatus*, the investigations of Seshappa and Bhimachar (1951, 1954 and 1955) have proved that the growth-rings are formed in association with the monsoon conditions of starvation and unfavourable weather. Menon (1950 and 1953) feels that the appearance of zonation in the hard parts of fishes may be the result of only a physiological internal rhythm in the fish, the external factors being of no consequence.

In the past, when growth-rings were found in the mackerel scales in India (Madras Fisheries Administration Report, 1935-36), it was assumed that the rings were winter rings as in the case of the fishes of temperate waters. But when it was found that a subsequent ring was not formed for the next winter, this explanation failed.

The present author suggested (Seshappa, 1958) that the rings are spawning marks, considering the season and the state of the gonads and also the fish-size connected with the occurrence of the rings. The present data are inclusive of the earlier data collected at Karwar also and it will be seen from Table 2 that the maximum percentage of rings are found in specimens with gonads in advanced stages of maturity, namely stages V and above, including 'spent and recovering spent' stages also. After examining a good number of specimens from different places it was noticed that rings occurred not only in spent individuals but also often in specimens that had not spawned but had the gonads in an advanced stage of maturity. The evidence thus points very largely in favour of a view that the rings are formed as a result of the physiological strain on the fish during the process of growth and ripening of the gonads. Thin margins, *i.e.* the commencement of ring-formation (indicated by the cessation of circuli formation), were clearly observed in specimens

with gonads in maturity stages IV-V during July-August 1967; smaller and immature specimens did not show this condition. Table 5 shows the results of more detailed observations made on the scale margins in mackerel samples, particularly of the smaller size-groups, during the period March 1969 to December 1970. It will be seen from the table that neither clear rings nor their beginnings in the form of thin margins were noticeable in the mackerel of either sex with gonads below stage III (excepting one or two instances where an abnormal indication of a thinning margin could be noticed). In individuals of stage III and IV, cases of thin margin were occasional and frequent respectively, while in still higher stages of maturity (including also spent fish) the occurrence of a thin margin has been the rule in all instances where a clearly formed ring is not already noticeable. The great majority of the 886 specimens examined during the period were of the small and medium sizes, these invariably having their gonads in the lower stages of maturity and not having either growth-checks in their scales or any beginnings of such rings in the form of thin margins. The larger sizes invariably have gonads also in advanced stages of maturity and show either the thin margins or completely formed rings in their scales. Table 3 shows the percentage of specimens with rings in the size-group 22-24.9 cm *total length*. As the samples cannot be considered as random samples the existence of two peaks in the monthly percentage figures may not be of much significance. Nevertheless while large numbers are available for October-November because that is the fishery season (and a natural bias is operative here) the percentage of specimens with rings is also the highest in these months, because this period marks the end of the main spawning season during and before which the cessation of growth occurs and scale-rings are laid down. While it is difficult to explain the trend of distribution of the percentage figures during the other months (because of the heterogeneous nature of the samples both in space and time), it is quite likely that these figures have something to do with the suspected second spawning season for the species within the year (see Virabhadra Rao, 1962). The formation of growth-rings as a result of the physiological strain seems not only possible but highly probable in the present case. Garrod and Newell (1958) have shown (in *Tilapia esculenta*) that rings are formed in the scales during breeding and brooding and that they may reflect a temporary mineral deficiency. They found that the calcium value and the moisture content of the ovary showed an apparent decline in the ripening and mature females of *T. esculenta*; the average values of calcium for the scales also showed a fall from the ripening and mature to the brooding condition, though there was some overlap between the different stages of maturation. The small percentage of abnormal specimens with rings and thin margins in the scales but with the gonads in the relatively not so advanced stages of maturity (*e.g.* III and IV) noticed in the present work (see Table 2) can be due to some erratic behaviour of this type in the mode of calcium depletion, the data summarised in Table 5 having clearly demonstrated the absence of thin margins in fish with immature gonads. The thin margins are fore-runners of the rings.

Now we come to the fourth point, namely, whether these rings can be used in age and growth work irrespective of the causes leading to their formation. The

answer to this depends on the periodicity in the occurrence of these rings and the regularity of the same in time and space. It has been stated above that the rings in *R. kanagurta* are formed as a result of the physiological strain associated with the growth and ripening of the gonads, and, of course, also of the spawning activity. While there is some evidence that there may be two spawning seasons for the species on the west coast within a year, it seems most unlikely from the data examined by the present author that the same individual fish spawns in two separate seasons. While the spawning is known to take place in two or more batches of ova, they appear to be all shed over a short period of time within the same season so that there is really no interval so long between the shedding of one batch of eggs and the next, as to cause the formation of two separate growth-rings, at least as a general rule. It is true that some specimens have shown two closely placed growth-checks, but these have been very rare. The present author believes after the examination of material from various centres and particularly from Karwar, Calicut and Mandapam that the individual mackerel recovers after each season's spawning activity for developing and spawning fresh batches of ova during the corresponding season again in the next year, this being repeated regularly year after year, until at last a stage is reached when the gonad can no longer produce further generative cells. The author and some other workers of the Institute (Dr. M.S. Prabhu, personal communication; Dr. N.G. Sproston, unpublished documents) have found in certain large specimens of the mackerel, the ovaries being represented by simple translucent but uncollapsed empty tubes with no conspicuous lining of generative cells on the walls. It is most likely that such instances are the actual final stages of the ovary in this species when no further recovery is possible. If this be so the rings formed in the scales as a result of the stress due to gonadial growth and ripening may be tentatively assumed to be formed once a year commencing from the second year of life and continuing until the above condition is reached. Accepting this view in the absence of evidence to the contrary, the rings of the scales can be used for determining the age of the fish at least for some years after the spawning starts, the age being one plus as many years as there are rings. On this criterion the Indian mackerel may be said to reach a size of 21-24 cm by the end of the second year, about 25-27 cm by the end of the third year and 28-29 cm by the end of fourth year of life. Individual specimens may occasionally go beyond these ranges also. Two rings have been frequently noticed in the present work in specimens above 25 cm and up to four rings have been noticed in the rare large specimens from Vizhinjam. A real difficulty in reading the rings accurately in the very large specimens, as already mentioned, is that the earlier-formed rings become faint because of the thickening of the scales with further growth, and the latter rings may be faint because of the naturally reduced intensity of the stress connected with the recovery of the gonads and spawning activity; the second and subsequent spawnings would themselves be presumably of much reduced intensity compared to the first spawning. However, no assertion on the points discussed in this paragraph is intended until the main assumptions are found justified.

Now, coming to the last of the questions listed at the beginning of this discussion circuli counts were taken from 427 individuals ranging in size from 11-11.9 cm group to the 25-25.9 cm group, to see whether the age of the fish could be fixed on any criterion in the case of the smaller sizes where the growth-rings do not occur. This study has proved the existence of a direct and significant correlation between the size of the fish and the average number of the anterior circuli. However, while the correlation is quite clear in terms of average size of fish and average numbers of circuli, for individual fish the range of variation is quite wide and not fully fixed. It would appear from the data for Calicut that specimens with an average of around 15-17 circuli in the scales have just completed one year of life, this being the number of circuli in the size-groups of 15-16.9 cm which would be just above the size at the end of the first year according to the present state of knolwedge.

Some clear rings were seen in the scales from the region immediately behind the operculum in the 12-16 cm group occasionally, but they did not occur frequently enough to be of any definite value.

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