AGE AND GROWTH OF THREE SPECIES OF SEERFISHES *SCOMBEROMORUS COMMERSOU, S. GUTTATUS* AND *S. L1NEOLATUS**

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ABSTRACT

Length-frequency an:(lysis indicates that the king seer *(Scomberomorus cotnmerson)* attains a size of 402 mim, 726 mm, 995 mm and 1186 mm total length at 1, 2, 3, and 4 years of age, respectively, the streaked seer *(S. Uneolatus)* reaches a size of 350 mm, 713 mm, 835 mm and 965 mm total length et 1, 2, 3 and 4 years, respectively, and the spotted seer *(S. guttatus* a size of 369 mm, 532 mm: and 640 mm at 1, 2, and 3 years, respectively. Back-calculated lengths of fish at the time of ring formation on otoliths figree closely with the results of length-frequency analysis. The maximum lengths of king seer, streaked seer and spotted seer met with in the catches are 1936 mm (33 kg), 980' mm (4.6 kg) and 705 mm (2.1 kg), respectively. The theoretical maximum lengths (Lac) computed by Bagenal or Rafail method for the von Bertsfeaffy growth equation are found to be 2081 mm (46.7 kg) for the king seer, 1683 mm (15.7 kg) for the male streaked seer, 1447 ram (24.3 kg) for the female streaked seer and 1278 mm (9.6 kg) for the spotted seer. All the three species develop two rings a year in their otoliths at a regular interval of six months. For all the three species, the exponent in the length-weight relationship is found to be close to 3.

INTRODUCTION

In spite of the commercial importance and wide distribution of seetfishes wihin the IndcHPecific region, information] on age and growth, so essential for an understanding of their population biology, is rather meagre (Krishnamoorthi 1958, Williams 1964, Srinivasa Rao 1978). Investigations were, therefore, initiated to eclucidate further information on the age and growth of three species of seerfishes from the southeast and southwest coasts of India during July 1967 through July 1969, and the results are presented here.

MATERIALS AND METHODS

Age determination was made by applying Petersen's method of length-frequency analysis, and also from growth checks found on otoliths (sagitta). The materials for the study included: (1) samples taken twice or thrice a week

* Formed part of the thesis approved for the award of Ph.D. degree, Madurai University.

on a random basis from the commercial, drift gillnet (76 mm mesh type) catches from Palk Bay (zone I) and the northern Gulf of Mannar (zone II) landed in the Rameswaram Island during July 1967 through July 1969; (2) weekly or fortnightly samples from the shoreseine catches from zones I and II during 1967-69; and (3) occasional samples during 1968-69 from the shoreseine, drift gill-net (64 mm and 130 mm mesh types), and troll line (70-90 mm hooks) catches from the central Gulf of Mannar (zone III) off Tuticorin, and the southeastern Arabian Sea (zone IV) off the Kanyakumari district coast. Total length of fish for the length-frequency data was measured from the origin of snout to the tip of upper caudal lobe flexed to the mid-longitudinal axis of the fish. For growth check studies, usually the left otoliths were oxitracted, but when broken, the right, and preserved dry.

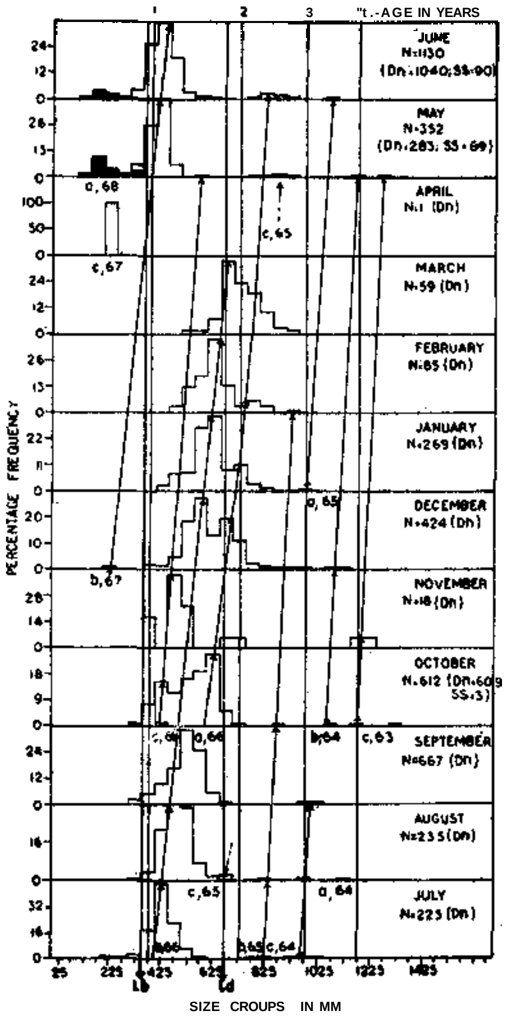

FIG. 1. Ktag seer; percentage length frequency distribution of fish from Palk Bay for successive months of the period July, 1967 through June, 1968 (dark and blank areas represent samples from shore seine (SS) and drift gillnet (Dn) catches respectively).

The section of the samples caught selectively by the 76 mm mesh-type drift gillnets was indicated in the length-frequency histograms by two vertical lines representing the selection parameters: l_e - the length at entry to the gear, and l_d - the escapement length, determined by Olsen's (1959) exponential model. The samples below the level of l_e were mainly from the shoreseines, and those beyond l_d mainly from the gillnets, but caught by a process of entangling. The growth of fish was determined by following the progression of modes between l_e and l_d and by extrapolation to the modes below and beyond the levels of l_e and l_d respectively. The progression of modes was traced by trend lines with arrows pointing to the position of the modes. Figure 1 for the king seer illustrates this method. In the scatter diagrams for the variables: time in months and modes, trend lines tracing the growth of successive broods by means of modal progression through time were fitted freehand. These lines were extrapolated (with reference to the growth lines for the younger broods) to intersect the time axis in order to resolve the periodicity and frequency of brood production each spawning season and also the growth of various broods through successive months (Figs. 2 to 4). The grand mean for the growth at age in months for the population was derived from the growth of individual broods. The broods and year classes that the various trend lines in the length-frequency histograms represent, were indicated at the foot of these lines by alphabets (for broods) suffixed by the year of brood origin (for year classes) as shown in Fig. 1.

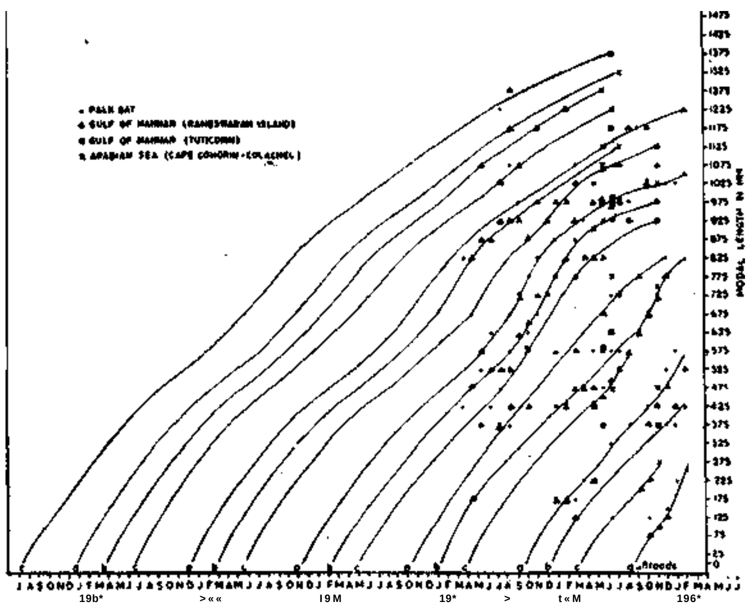

FIG. 2. King seer; growth of individual broods on the basis of the modes in the length frequency distribution for successive months.

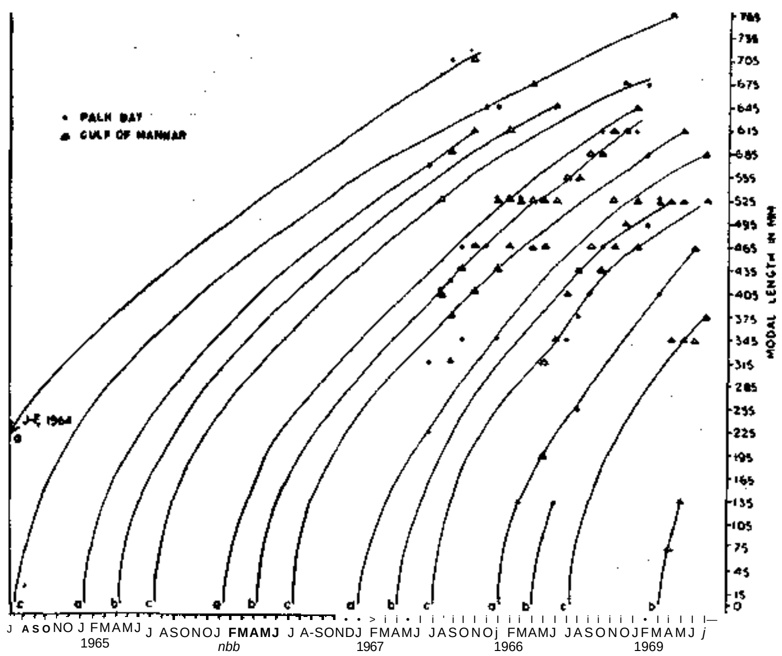

FIG. 3. Spotted seer; growth of individual broods on the basis of the modes in the length-frequency distribution foT succesisive months.

The standard terminology described by Jensen (1965) for otolith reading is followed here except the term 'ring' which is a synonym of Jensen's 'zone'. The otoliths were examined in xylene under reflected light in a black background at 12.5 magnification. Otolith radius (R) and ring radii (r_n) were measured from the centre of the nucleus in the direction of the posterior-most tip of the postrostrum along which the rings were clear, and the measurements expressed in micrometer divisions (1 m.d. = 100 microns). Within the nucleus may often be present a hyaline zone, presumed to have been formed as a result of some critical phase in the early life of the fish, and hence termed the juvenile ring ($r_?$) Periodicity of ring formation was resolved by studying the otolith marginal growth, $R - r_n$, and the rate of marginal growth, $\frac{R - r_n}{r_n - r_{n-1}}$, where r_{n-1} means ring radius preceding r_n For this purpose, a graphic method given by Yang et al (1969) and Yukinawa (1970) was adopted after some modification. The modification was found necessary in order to overcome the difficulties arising from the production of a number of broods within the same spawning season which is rather prolonged.

The growth relationship between otolith radius and total length of fish was established by a linear regression. Back calculations for fish length at ring

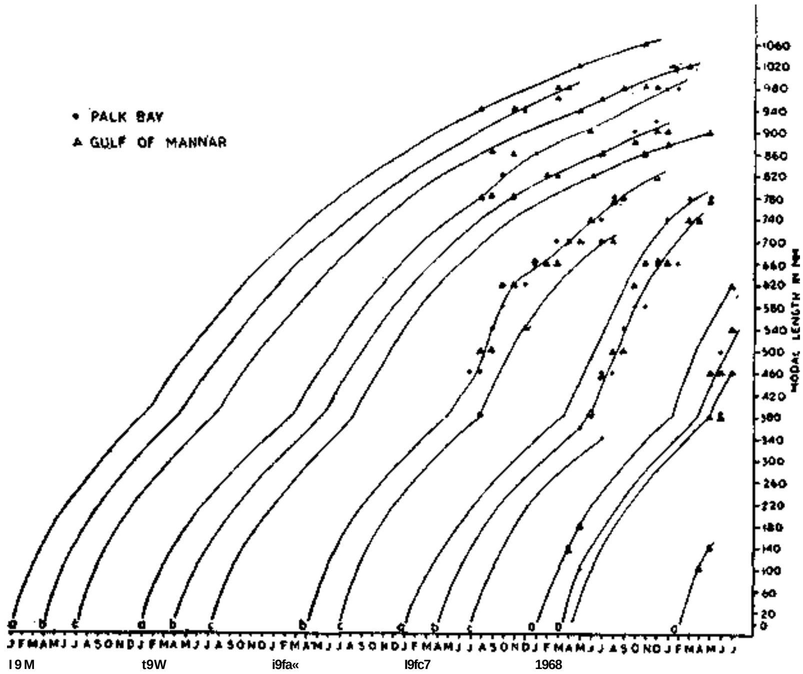

FIG. 4. Streaked seer; growth of individual 'broods on the basis of the modes in the length frequency distribution' for successive months.

formation were made using the direct proportionality of Dhal-Lea (see Hile 1970), its modification by Fairbridge (1951) to account for variations, if any, from strict proportionality between the growth of otolith and fish length, Lee's (1920) linear regression of fish length on otolith radius, and Chugunova's (1959) equation to account for the intercept value in Lee's formula. Bagenal's (1955) least squares solution and Rafail's (1973) iterative procedure were followed for fitting the growth curves of the von Bertalanffy type as given in an integrated form by Reverton and Holt (1957). The length-weight relationship was determined by applying a simple allometric formula.

RESULTS

Length-frequency analysis

For all the three species, each year class comprised three broods: a minor brood (a) released during January-February, a major brood (b) released during April-May, and another minor brood (c) during July-August (Figs. 1 to 4; Tables 1 & 2). The difference in lengths at age among various broods from different zones were insignificant (Tables 1 & 2). Lengths at age derived from modal progression in the length frequency histograms and scatter diagrams of months-modes (Fis. 2 to 4) agreed closely with each other (Tables 1 & 2).

Otolith readings

The **morphology of left otolith of king seer is illustrated in Fig. 5.**

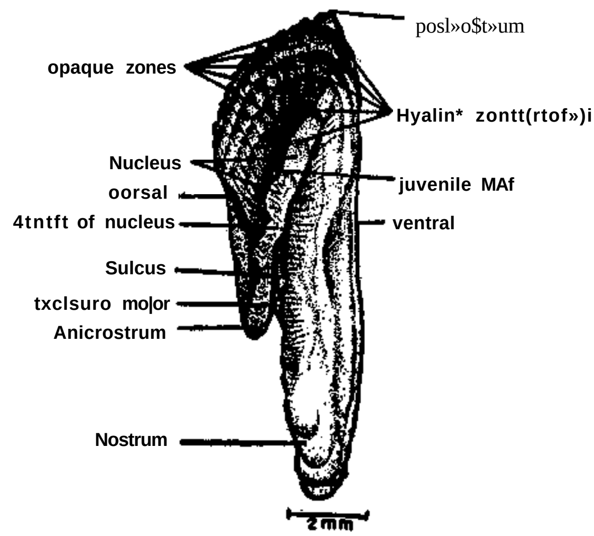

FIG. 5. King seer; morphology of left otolith (sagitta).

Otolith radius-fish length relation: For the king seer, linear regression fitted for the indeterminates did not indicate any variation between zones (F = O). There was no variation either between sexes (F = O). However, the males from different zones exhibited some variation (F = 2.6; d.f. = 107 & 2), and the females from different zones varied at 5% level (F = 4.66; d.f. = 2 & 121). Ignoring

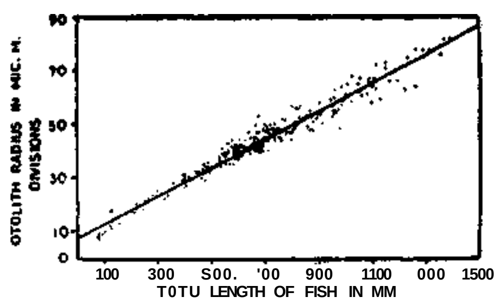

FIG. 6. King seer; relation betweea total length of Ash and otolith radius.

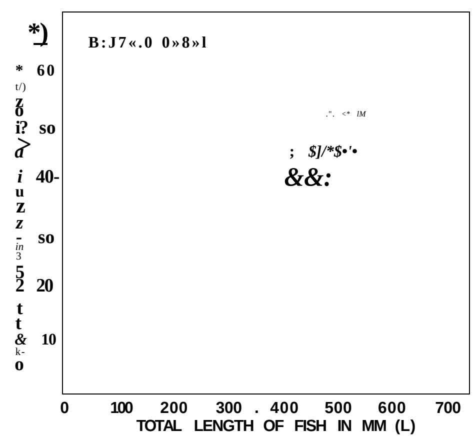

FIG. 7. Spotted seer; relation between total' length of fish and otolith radius.

TABLE 1. *Lengths (mm) at age (years) for three species of seerfishes based on length-frequency analysis.* (PB = Palk Bay; NG = northern Gulf of Mannar)

Species	King seer								Spotted seer						SVreaked seer							
Age in years	1		2		3		4		1		2		3		1		2		3		4	
Zone	PB	NG	PB	NG	PB	NG	PB	NG	PB	NG	PB	NG	PB	NG	PB	NG	PB	NG	PB	NG	PB	NG
Brood & year class																						
a, 64	—	—	—	—	—	—	—	1225	—	—	—	—	—	—	—	—	—	—	—	—	—	—
b, 64	—	—	—	—	—	—	—	1200	—	—	—	—	—	—	—	—	—	—	—	—	—	—
c, 64	—	—	—	—	—	—	—	H67	—	—	—	—	—	—	—	—	—	—	—	—	—	965
b, 65	—	—	—	—	978	1012	1175	—	—	—	—	—	—	640	—	—	—	—	—	835	—	—
c, 65	—	—	—	—	—	1025	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
a, 66	—	—	750	742	975	—	—	—	—	—	535	—	—	—	—	—	—	—	—	—	—	—
b, 66	—	—	750	750	—	988	—	—	—	—	547	525	—	—	—	—	730	700	—	—	—	—
c, 66	—	—	638	775	975	—	—	—	—	—	—	503	—	—	—	—	—	—	—	—	—	—
a, 67	401	425	694	—	—	—	—	—	355	—	—	530	—	—	—	—	—	—	—	—	—	—
b, 67	405	388	700	692	—	—	—	—	—	—	543	525	—	—	350	—	693	730	—	—	—	—
c, 67	—	—	—	—	—	—	—	—	360	379	—	532	—	—	—	—	—	—	—	—	—	—
a, 68	388	—	—	—	—	—	—	—	374	—	—	—	—	—	—	—	—	—	—	—	—	—
b, 68	332	450	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
c, 68	—	—	—	—	—	—	—	—	—	375	—	—	—	—	—	—	—	—	—	—	—	—
Mean for broods a:	395	425	722	742	975	—	—	1225	364	—	535	530	—	—	—	—	—	—	—	—	—	—
b:	369	419	725	721	978	1000	1175	1200	—	—	545	525	—	640	350	—	711	715	—	835	—	—
c:	—	—	638	775	975	1025	—	1167	360	377	—	518	—	—	—	—	—	—	—	—	—	965
Population mean	382	422	706	746	976	1013	1175	1197	362	377	540	524	—	640	350	—	711	715	—	835	—	965
Zones combined	402		726		995		1186		369		532		640		350		713		835		965	

TABLE 2. *Lengths (mm) at age (years) for three species of seerfishes based on the scatter diagrams of modes - months* (PB = Palk Bay; NG = northern Gulf of Mannar; CG = Central Gulf of Mannar; AS = Arabian Sea).

Species	Khg seer					Spotted seer				Streaked seer			
Ag2 in year	1	2	3	4	5	1	2	3	4	1	2	3	4
Zone													
PB	375	725	975	1175	—	360	525	—	—	350	700	860	980
-NG	425	737	100©	1175	—	360	525	635	705	380	700	—	973
CG	375	—	—	—	—	—	—	—	—	—	—	—	—
AS	—	750	—	—	1325	—	—	—	—	—	—	—	—
Mean	392	737	988	1175	1325	360	525	635	705	365	700	860	977

this variation as of little biological significance, the king seer in the study zones may be deemed to be of a homogeneous stock, and a common regression was fitted for the entire sample (Fig. 6; Table 3). In the case of spotted seer, straight-line regression fitted for the indeterminates, males, and females did not exhibit any significant variation (F = 1.514; d.f. = 181 & 2), and hence, a common regression was fitted (Fig. 7; Table 3). The regression fitted for the male and female streaked seer (Table 3) differed significantly from each other at 1 % level (F = 7.57; d.f. 1 & 37), and this warranted separate regressions for the sexes (Fig. 8).

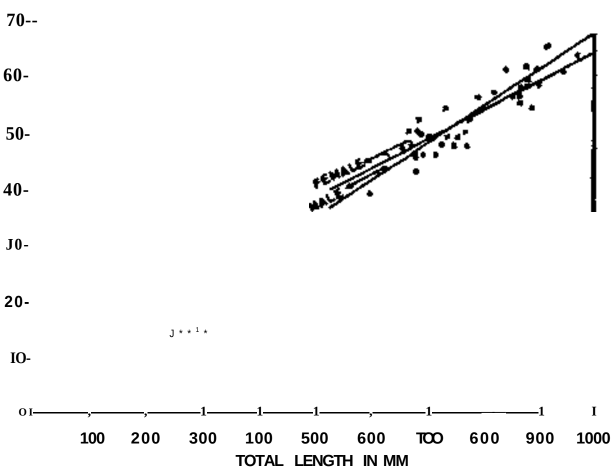

FIG. 8. Streaked seer; relation between total length of fish and otolith radius, separately for males and females.

Distribution of rings: Otoliths exhibiting different number of rings are shown in Fig. 9 to 11. Although some degree of overlap was observed in the frequency

TABLE 3. *Parameters of equations fitted for otolith radius (R in m.d.) - fish length (L in mm) relation (Eq.* 1), *back calculation of fish lengths* 1 *in mm) at ring formation* r_Q in m.d.) (Eqs. 3, 4, & 5), *growth* l_t *in mm and* W_t *in g)* (Eqs. 6 & 7) *and length - weight relation* (L *in cm and* W *in g)* (Eq. 8) *for three species of seerfishes.*

S.No.	Formulae	Parameters	King seer	Spotted seer	Streaked seer Female	Streaked seer Male
1.	R = a + bL (Eq. 1)		7.36 0.053	2.76 ».087	2.5 0.065	13.0 0.051
2.	L_n - L *I l l l* (Eq. 3) R - a		7.36	2.76	2.5	13.0
3.	l_n = a + br_n (Eq. 4)	a b	-96.00 17.90	15.J7 10.47	41.93 13.80	70.0 13.6
4.	l_n = a + (L-a) (Eq. 5)		-96.00	15.57	41.93	70.0
5.	$1_{\{}$ = La (1 - e -k (t-to)) (Eq. 6)					
	A. *For lengths at half tears*					
	i) Bagenal method (Eq. 6-1)	Loo k t.	2450 0.07696 -0.0575	1273 0.09531 -0.6573	1598 0.08618 -1.7786	2124 0.05827 -2.2119
	ii) Rafail, 1st kerauon (Eq. *6-2)*	Loo k t.	2240 0.08565 -0.19148	1281 0.09021 0.9091		
	m) Rafail, 2nd iteration (Eq. 6-3)	Loo k 	2203 0.08831 -0.15808			

TABLE 3. ***(Continued)***

S.No.	Formulae	Parameters	King seer	Spotted seer	Streaked seer Female	Streaked seer Male
	B. *For lengths at complete years*					
	i) Bagenal method (Eq. 6-4)	L_∞			1447	1683
		k			0.22314	0.18232
		t_0			-0.51225	0.66433
	ii) RafaSl, 1st iteration (Eq. 6-5)	L_∞	2081	1278		
		k	0.18317	0.18007		
		t_0	-0.15*55	-0.4654		
6.	$W_t = W_\infty (1-e^{-k(t-t_0)})^3$ (Eq. 7)					
	A. *For weights at half years*					
	i) Bagenal method (Eq. 7-1)	W_∞	62760	9077		
		k	0.0758	0.1C093		
		t_0	-0.5972	-1.0250		
	ii) Rafail, 1st iteration (Eq. 7-2)	W_∞	46713	9565		
		k	0.09188	0.09811		
		t_0	-0.27492	-1.0444		
	iii) Rafail, 2nd iteration (Eq. 7-3)	W_∞	44290			
		k	0.09498			
		t_0	-0.23331			
	B. *For weights at complete* ***years***					
	i) Rafail, 1st iteration (Eq. 7-4)	W_∞	39027	8540		
		k	0.21185	0.21256		
		t_0	-0.030016	-0.45267		
7.	$W = cL^n$ (Eq. 8)	c	0.009614	0.01011	0.004167	0.004394
		n	2.8577	2.dh05	3.0443	3.0372

distribution of ring radius (Figs. 12 to 14) and length of fish according to ring count there was a clear cut increase in the ring number with the growth of fish and otolith. Mean radii of each ring are given in Table 4 according to ring groups.

Periodicity of ring formation: In the king seer population, high incidence of otoliths with hyaline margin in January, April, July, and October (Table 5) indicated ring formation four times a year. The lengths at which the fish come to possess two, four, six eight, and ten rings in their otoliths were found to agree closely with the lengths at 1, 2, 3, 4, and 5 yeras of age, respectively, determined by the length-frequency method. This agreement suggested that the fish developed two rings a year. The time of ring formation in the three broods and the time interval between two successive rings were determined as follows.

The size-frequency distribution of the marginal growth and the rate of marginal growth of otoliths for successive months from January through December revealed a multimodal pattern, the modes apparently representing the various broods of each year class. The graphic representation of the marginal growth data for the spotted seer is illustrated in Fig. 15. For the other species only the summation of R — r or T? ___ B_ / $r_u \sim r_{n-l}$ for the successive months is illustrated (Fig. 16). The modes marked in dark circles under 'the sum column represent the marginal growth of broods a (January-February) and c (July-August) and those marked in blank circles represent the marginal growth of brood b (April-May). The broken lines indicate that broods a and c form new rings in January and July, and brood b in October and April at a regular interval of six months (Figs. 15 & 16). The relation between the time of brood origin and periodicity of ring formation is indicated by a spawning scale in the form of three parallel lines issuing from the time of origin of the three broods (Fig. 15).

For the spotted seer population, the incidence of otoliths with a hyaline margin was high in January, April, and October (Table 5). Whether this was true in July also as for the king seer, is not known for want of samples. However, Fig. 15 reveals that broods a and c developed rings every January and July, and brood b every October and April as the king seer broods.

In streaked seer the incidence of hyaline margin was high in January, April and October (Table 5). Samples of otoliths were not available during June-September. However, Fig. 16 indicates the periodicity of ring formation to be the same (in both the males and females) as for the other two species.

Back calculations: The values for the parameters of various equations used in back calculation of lengths at rings are presented in Table 3. Back-calculated lengths at rings according to ring groups are given in Table 7. Back calculation

TABLE 4. *Mean ring radii* (r) *in m.d. for each ring group of king seer* (A) *spotted^ seer* (B), *male streaked seer* (C), *and female streaked seer* (D). R = *mean otolith radius.*

	group	of fish		r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8	r_9	r_{10}	r_{11}	R
(A)	?	3	14.7												19.3
	I	6	14.0	20.0											24.4
	II	39	•15.3	20.4	26,8										32.2
	III	74	15.2	20.6	27.4	36.4									41.5
	IV	67	15.0	20.1	26.8	35.7	43.7								46,5
	V	23	14.9	20.2	26.3	35.3	43.3	50.7							54.0
	VI	17	15.1	20.0	27.0	35.4	43.1	50.3	57.7						60.4
	VII	15	14.6	19.6	26,0	34.9	42.2	48.9	57.2	62.7					65.7
	VIII	1	14.0	20.0	25.0	32,0	40.0	45.0	55.0	62.0	65.5	-			66.0
	IX	3	14.3	19.2	24.3	31.8	40.3	46.7	55.5	62,0	68.7	74.0			77.2
	X	3	12.3	1'8.3	26.2	34.0	40,5	47.8	54.7	62.0	67.0	71.7	76.3		78.2
	XI	2	15.5	22.0	27.0	35.5	44.0	52.5	58.8	65.5	70.5	74.5	79.5	84	84.5
		r_n	14.6	20.0	26.3	34.6	42.1	48.8	56,6	62.8	67.9	73.4	7.79	84	
(B)	?	2	16.0												18.5
	II	2	16.0	21.0	30.0										36.8
	III	52	14.9	20.1	28.6	37.0									41.5
	IV	71	15.5	20.6	2«.5	36.1	42.9								47.3
	V	31	14.7	21.0	28.1	35.7	43.1	49.1							53.0
	VI	19	15.0	20.5	27.7	35.2	41.5	47.9	53.7						56.5
	VII	2	—	18.0	26.8	34.8	41'.8	48.0	53.5	57.5					60.0
		r_n	15-.4	20.2	28.3	35.8	42.2	48.3	53.6	57.5					
(C)	HI	1	16.0		25.0	35.0									39.0
	•IV	7	19.0	20.8	28.4	35.0	44.3								46.8
	V	4	16.5	20.4	27.5	33.4	39.0	45.0							48.9
	VI	3	17.0	21.7	29.7	35.8	42.5	49.0	54.3						58.5
	VII	1	—	20.0	25.0	34.0	41.0	48.0	53,5	59.0					61.0
	VIII	1	17.0	22.0	26.5	36.5	41.0	45.0	52.0	56.0	59.0				61.5
		r_n	17.1	20.9	27.0	35.0	41.6	46.8	53.3	57.5	59.0				
(D)	IV	4	19.9	20,8	28.4	35.3	44.3								49.1
	V	8	16,7	20.2	26.4	34.3	40.9	46.9							49.4
	VI	10	16.7	21.7	27.9	35.6	42.8	48,6	54.2						47.2
	VII	1	18.0	22.5	29.0	35.5	40.5	49.0	55,5	61.0					65.0
	VIII	1	18.0	24.0	35.5	37.0	45.5	52.0	5«.0	61.5	63.0				63.5
		r_n	17.7	21.8	28.4	35.5	42.8	49.1	55.9	61.3	63.0				

using Eq. 3 (Table 3) indicated Rosa Lee phenomenon (i.e., estimated lengths foi? a given age tend to be smaller if derived from the measurements on older fish) in the growth of king seer, but the results of Eq. 2 revealed a reversal of this phenomenon. Therefore, there is no real influence of this phenonmenon on the king seer, and the apparent influence could be due to the errors inherent in the methods used for back calculations (Chugunova 1959). Correction for disproportionality between the growth of otolith and length of fish is achieved by

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FIG. 9.

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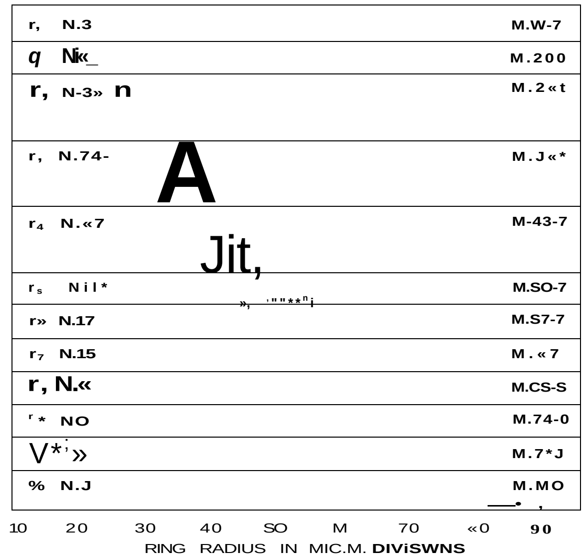

FUG. 12. King seer; frequency distribution of ring radius of eacb ring group ranging from the juvenile ring group (r?) to the eleventh ring group (m)

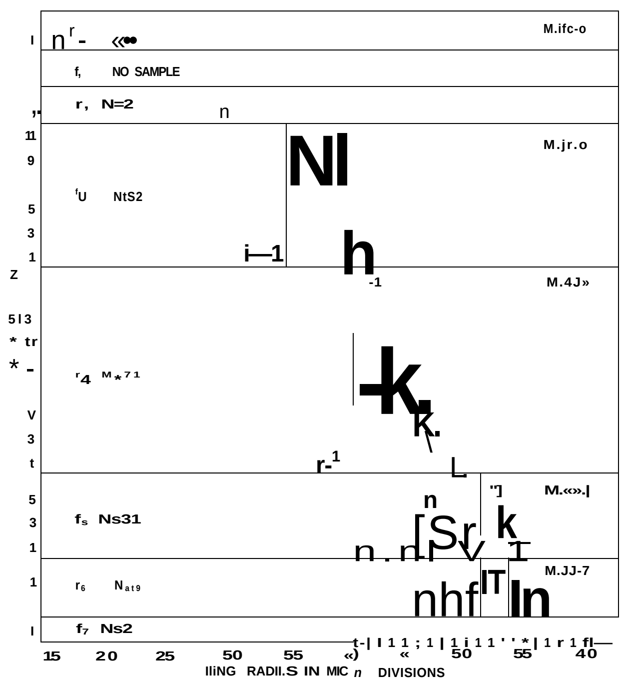

FIG. 13. Spotted seer; frequency distribution of ring radius **of each** ring **group ranging** from **the** juvenile ring group (r>>) to the seventh ring **group (r ?)**

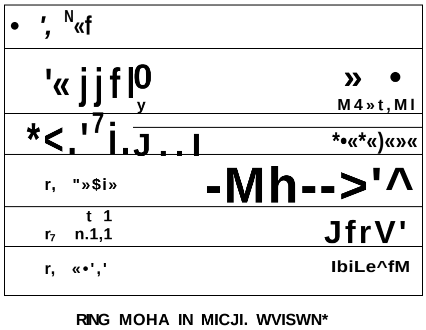

FIG. 14. Streaked seer; frequency ddstriibutJcxn of ring radius of each ring group ranging from the th'rd *(tj)* to the eleventh ring (m), separately for males and females.

applying Eqs. (3) or (5). Therefore, length estimates from either of these equations could be used for fitting growth curves. For the king seer and spotted seer, estimates from Eq. (3) were used for this purpose while for the streaked seer those from Eq. (5) were used. Goodness of fit of estimates from other equations was tested against those from Eqs. (3) and (5) by comparing the sums of squares of deviations ($2d^2$). Smaller the $2d^2$ value, closer the estimates between the equations tested (Table 8).

GROWTH CURVES

The values for the growth parameters in the von Bertalanffy equations are given in Table 3. On the basis of comparison of sums of squares of deviations between empirical data and length or weight estsimated from growth equations, Rafail's method is found to fit the growth curves for king seer and spotted seer better than Bagenal's method while the reverse is true for streaked seer. Since the weight-at-age data for streaked seer were not amenable to the growth equation, Woo was estimated directly from Loo by applying the length-weight

TABLE 5. *Percentages of hyaline and opaque margins of otoliths of king seer* (A), *spotted seer* (B), *and streaked seer* (C) *for each month.*

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
A Hyaline	84	44	29	59	0	—	86	45	34	74	40	48
Opaque	16	56	71	41	100	—	14	55	66	26	60	52
B Hyaline	80	—	33	67	40	—	—	36	45	53	20	IS
Opaque	20	—	67	33	60	—	—	64	55	47	80	82
C Hyaline	83		34	100	50	—	—	—	—	50	34	34
Opaque	17	—	66	0	50	—	—	—	—	50	66	66

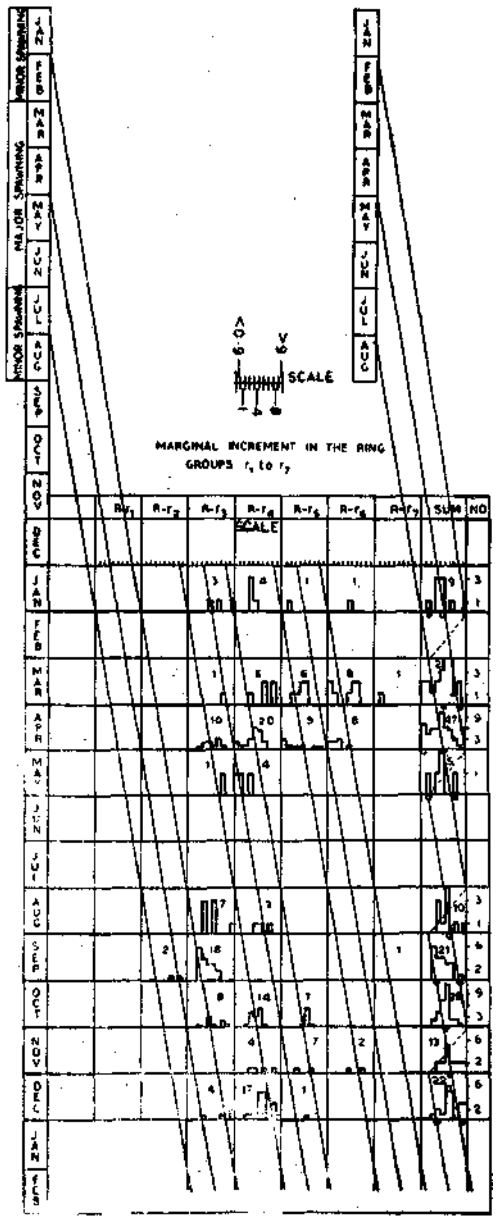

FIG. 15 Spotted seer; monthly changes of marginal growth ($R-r_n$ in micrometer divisions) of otoliths; numerals denote the number of fish.

relationship, and was found to be 15740 g for the male and 24330 g for the female. For all the three species, the exponent in the length-weight relation was close to 3, the value in the cubic law (Table 3).

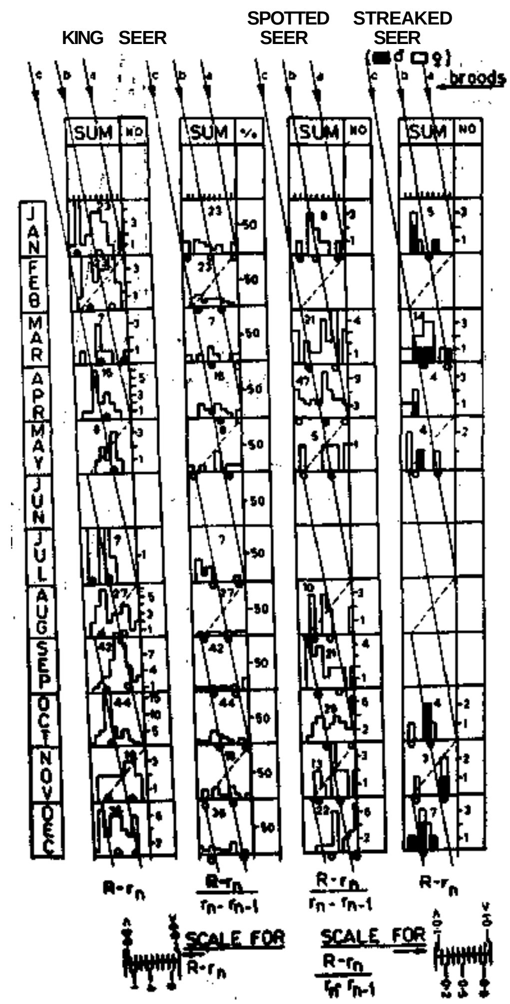

FIG. 16. Monthly changes in the sum of $R-r_n$ or $\frac{R-r_n}{r_n-r_{n-1}}$ of otoliths of seerfishes. Numerals indicate the number of fishes.

DISCUSSION

The determination of age and growth of warmwater fishes based on length-frequency data poses a problem because of multiple broods comprising each year class (Dutt 1969) as in the case of the seerfishes. Yet, if a reasonably accurate method is available to resolve the polymodal frequencies into their Gaussian components, it would be easier to follow the identity and growth of each brood (Pantulu 1969). That the scatter diagram of months-modes is a simple and effective method for this purpose, is obvious from this study (Devaraj, in press). The incorporation of a spawning scale in the modified Yang et al

TABLE 6. *Mean back calculated lengths* (7 *in mm) of king seer at ring formation derived from Eqs.* (2) *and* (3) *for various ring groups.*

Ring group		No. of fish	'?	'.	*h*	13	I4	1 5	*h*	W	Is	19	ho	In
(Eq. 2)	?	3	183											
	I	6	183	265										
	II	39	224	299	392									
	III	74	230	310	414	549								
	IV	67	344	325	433	579	706							
	V	23	243	332	429	575	705	826						
	VI	17	251	330	444	582	710	827	950					
	VII	15	245	336	444	599	720	834	975	1069				
	VIII	1	253	361	451	577	722	812	976	111«				
	IX	3	253	323	411	S3*	680	786	936	1046	1182	1250		
	X	3	214	317	454	589	701	828	947	1072	1160	1232	1320	
	XI	2	254	359	442	582	721	859	961	1072	1155	1220	1301	!374
		r	230	323	431	574	708	825	958	1075	1164	1234	1311	1374
(Eq. 3)	?	3	148											
	I	6	125	238										
	II	39	151	247	369									
	III	74	144	243	368	533								
	IV	67	148	247	377	550	706							
	V	23	142	242	357	526	677	816						
	VI	17	145	237	368	525	669	804	942					
	VII	15	139	235	3<58	529	669	798	958	1063				
	VIM	1	135	257	358	500'	6>63	764	968	1110	1181			
.	IX	3	129	221	316	456	615	734	89-8	1019	1144	1243		
	X	3	94	209	360	508	633	772	904	1043	1138	1228	1316	
	XI	2	146	262	352	504	656	809	923	1042	1131	1203	1292	1374
		7	137	240	35«	514	661	7«5	932	1055	1149	1224	1304	1374

(I960) graphic model adopted in this study resolved the periodicity of ring formation in the three broods constituting each year class of each of the three species studied (Devaraj, in press). Among the Scombridae to which seerfishes belong, some species of *Thunnus* develop only one ring a year (Yabuta and Yakinawa, 1963; Yukinawa 1970) as in *Scombermorus cavalla* from Florida (Beaumariage 1973) while the other species of *Thunnus* develop two rings a year (Yabuta et al 1960, Yukinawa and Yabuta 1963, Yang et al 1969) as now observed in the three species of *Scamberomorus* from the Indian seas.

Changes in the increments of ration, i.e., food consumed per unit time (Ivlev 1955) and the increments in 'the body weight between successive years of life indicated that all the three species of seerfishes experienced conditions of stress while they became sexually mature the first time at an age of 2-3 years, but stress was not evident subsequently. Besides, there appeared to be no de-

TABLE 7. *Mean back calculated lengths of king seer* (A), *spotted seer* (B), male *streaked seer* (C), *and female streaked seer* (D), *at ring formation using various equations* (L = mean length in mm of fish of different ring groups; W = empirical weight in g corresponding to the moan length derived from Eq. 3 for the king seer and spotted seer, and Eq. 5 for the streaked seer).

		'?	h	h	h	U	h	h	h	h	I9	'IO	
A	Eq.2	230	323	431	574	708	825	958	1075	1164	1234	1311	1374
	Eq.3	137	240	358	514	661	785	932	1055	1149	1224	1304	1374
	Eq,4	165	263	375	523	658	778	916	1029	1120	1218	1299	1408
	Eq.5	166	265	381	533	676	797	941	1061	1153	1229	1306	1373
	L	241	321	471	627	760	878	993	11-21	1191	1303	1352	1382
	W	—	85	265	745	1530	2500	4083	5820	7423	8896	10650	12350
B .	Eq.2	165	221	310	3'91	465	535	596	655				
	Eq.3	150	203	297	382	453	531	594	653				
	Eq.4	177	227	312	390	459	522	578	61'8				
	Eq.5	167	223	312	393	466	536	596	655				
	X	188	—	408	449	506	583	613	683				
	W	_	57	167	340	551	865	1188	1552				
C	Eq.2	254	309	401	518	611	693	789	864	906			
	Eq.3	228	285	382	506	602	686	785	861	904			
	Eq.4	278	331	415	524	615	687	777	836	856			
	Eq.5	281	335	421	532	622	700	794	867	907			
	L	—	—	—	600	670	725	843	897	944			
	W	—	183	368	750	1207	1729	2537	3316	3805			
D	Eq.2	259	314	417	517	622	720	826	896	959			
	Eq.3	89	169	295	431	571	693	803	886	957			
	Eq.4	310	367	457	553	652	738	830	903	927			
	Eq.5	307	364	452	548	645	742	833	900	960			
	L	. _	—	—	—	685	749	862	912	967			
	W	.—	242	468	840	1377	2105	2992	3786	4608			

finite relationship between the periodicity of spawning and ring formation (Deva-faj 1977). Therefore, the process of spawning does not seem to be the agency bringing about ring formation. In the case of the Florida king mackerel *(S. cavalld)* which is a protracted spawner as the Indian species of seerfishes, Beaumariage (1973) observed ring formation on otoliths when there was oocyte differentiation even in specimens too young to be sexed macroscopically and initial yolk deposition in the vitellogenic oocytes. He also stated that "Somatic growth is apparently retarded as energy is annually required for yolk formation

TABLE 8. *Comparison of the sums of squares of deviations* ($2d^2$) *of lengths at rings back calculated by using four different models.*

		King seer	Spotted seer	Streaked seer Male	Streaked seer Female
	Eqs (3) & (2)	21077	742	———	
	Eqs (3) & (4)	3947	2463	———	
$2d^2$	Eqs (3) & (5)	2047	948	5419	85345
between:	Eqs (5) & (2)			1477	5765
	Eqs (5) & (4)			4185	1231

regardless of fish maturity." Apparently, differentiation of the gametocytes is responsible for ring formation, and seems to take place once a year in such species as *S. cavalla* whose rings were found to be annuli, but twice at half yearly intervals in those as the Indian seerfish.es which formed two rings a year. Since Menon (1953) and Devaraj (1977) have pointed out the doubtful role of temperature, food, spawning, etc, in the formation of growth checks in both temperate and warmwater fishes, the causative factor should be one of the many internal rhythmic events such as gametocyte differentiation referred to above.

In the case of king seer, lengths at age estimated from otolith readings agreed fairly well with those derived from length-frequency analysis. For the spotted seer, the lengths at 1, 2, and 3 years determined by the length-frequency method were closer to the lengths at II, 2i and 3i years respectively, estimated from otolith readings. This anomialy is probably due to the limitations of the length-frequency data to meat the requirements of Petersen's mehthod fully (Watson 1964). Krishnamoorthi (1958) stated that the third-year-class spotted seer attained 385 mm standard length (=491 mm total length). If he meant by the third year class the two year old fish, then there is marked agreement between his and the present estimates. Based on the length frequency analysis, Srinivasa Rao (1978) estimated the lengths of the spotted seer from Waltair to be 280 mm, 425 mm, 530 mm, 610 mm, 670 mm, 720 mm, and 770 mm respectively at 1, 2, 3, 4, 5, 6 and 7 years of age. The above estimates are in standard length to fleshy peduncle (Dr. K. Srinivasa Rao, personal communication)), and their total-length equivalents are 337 mm, 513 mm, 641 mm, 738 mm, 811 mm, 872 mm, and 933 mm, respectively. The lengths at 1, 2, 3, and 4 years of age estimated from length-frequency analysis in the present study (Table 2) agree very well with the above estimates by Srinivasa Rao. Back-calculated length of male and female streaked seer at corresponding ages did not differ significantly from each other. However, length at age from length-frequency analysis were closer to the back-calculated estimates for males than for females.

The record size of a king seer measuring 2 meters length and 52 kg weight caught from the Australian waters (Marshall 1964) matches well with the asymptotic size based especially on the Bagenal's method. A 1936 mm long and 33 kg king seier caught from Palk Bay in October 1975 .appears to be the record for the Indian seas, and this size is fairly closer to the asymptotic size based on Rafail's method (Table 3). The maximum size of spotted seer (705 mm length and 2070 g weight), male streaked seer (940 mm length and 4250 g weight), and female streaked seer (980 mm length and 4553 g weight) met with in the present study zones were much less than their asymptotic sizes (Table 3).

ACKNOWLEDGEMENTS

I am indebted to Dr. S. Jones for suggesting this study, to Dr. R. V. Nair and laitei Dr. K. V. Sekharanj for guidance, and to Dr. E. G. Silas, Dr. <S. Z. Qasim, Mr. G. Venkataramian, Dr. S. Ramamurfhy, Mr. M. H. Dhulkhed, and Dr. P. S. B. R. James for their encouragements and valuable suggestions. The work was initiated under a research fellowship awarded by the Ministry of Education, Government of India.

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