SOME OBSERVATIONS ON THE BIOLOGY OF *LIZA MACROLEPIS* (SMITH) AND *MUGIL CEPHALUS* LINNAEUS (MUGILIDAE) WITH NOTES ON THE FISHERY OF GREY MULLETS NEAR MANDAPAM

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INTRODUCTION

Chidambaram and Kuriyan (1952) gave a brief account of the grey mullets (*Mugil* spp.) of Krusadai Island in the Gulf of Mannar. The present study on the biology of *Liza macrolepis* (Smith) and *Mugil cephalus* Linnaeus from the Palk Bay was taken up since no information on these fishes is available. The food habits of *Liza macrolepis* and *Mugil cephalus* and the shedding of gill raker processes in grey mullets have been dealt with elsewhere. (Luther 1962 & 1964)

MATERIAL AND METHODS

Material for this study was collected from the sea (Palk Bay) and the salt water lagoon near Mandapam (09°17′N, and 79°06′ E). While the fishing for grey mullets is regular with moderate catches in the lagoon for a major part of the year, it is irregular in the sea. Most of the material for this study was collected from the lagoon at fortnightly intervals during the period, April 1958 to December 1960. Length to the caudal fork (LCF) was taken as standard measurement throughout the study. During the later part of the study (1959-60) as many fish as possible were measured in the field. Rest of the studies were made on fish preserved in 5% formalin..

Environment.—The general ecological and fisheries characteristics of the salt water lagoon near Mandapam have been given by Tampi (1959). Normally the lagoon is subjected to four types of ecological conditions every year as also observed by Pillai (1955). They are :

1. A period of dry season between June and September when a major portion of the lagoon remains in a semidried state with scattered little pools of water confined to central region of the lagoon.
2. Inundation of the lagoon with rain water during October-November soon after which a rich growth of algae and planktonic organisms occur.
3. Opening of the two bars towards the end of October or beginning of November resulting in an uninterrupted tidal flow into and from the lagoon.
4. Closing up of connections between the sea and the lagoon during March-April on account of the calmer conditions that prevail in the Palk Bay at this time.

However, the four types of ecological conditions mentioned above could not be demarcated in the year 1958 due to unusual rainfall in April and May.

I. *Liza macrolepis* (Smith)

The length-weight relationship, condition factor, maturity and spawning, size at first maturity, sex ratio, age and growth, parasites, and methods of fishing have been studied for this species.

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship of *L. macrolepis* was determined by using the equation $W=aL^n$(Le Cren, 1951). A total of 293 fish ranging in size from 73 mm to 247 mm from the lagoon and 97 fish ranging in size from 120 mm to 299 mm from the sea was employed for the purpose. The observed values of lengths and weights of individual fishes were transformed into logarithmic values and the equations were calculated by the method of least squares. Males, females and indeterminants were treated separately and were analysed by the Analysis of Covariance. The relevant details are given in Tables I to III.

TABLE I

Statistics of the length-weight relationship of males, females and indeterminants of L. macrolepis *from the lagoon*

Sex	N	SX	SY	SX^2	SY^2	SXY
Male	132	280·2371	191·3204	595·5798	282·8880	408·0215
Female	135	294·3523	218·9271	642·8467	364·6238	480·4842
Indeterminant	26	50·7138	25·7660	98·9615	25·9704	50·3783

N=Number of fish.
SX^2, SY^2, SXY=Sum of squares and products.
SX, SY=Sum of logarithmic values of length and weight respectively.

TABLE II

Regression data of length-weight relationship of males, females and indeterminants of L. macrolepis *from the lagoon*

Sex	D.F.	Sums of squares and products			b	Errors of estimate	
		x^2	xy	y^2		D.F.	S.S.
Male	131	0·6341	1·8467	5·5888	2·9123	130	0·2106
Female	134	1·0446	3·1383	9·5956	3·0043	133	0·1652
Indeterminant . . .	25	0·0427	0·1209	0·4363	2·8314	24	0·0940

D.F.=Degrees of freedom.
b=Regression coefficient.

TABLE III

Test of significance

Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F	5% F
Deviation from individual regressions within sexes .	287	0·4698	0·0016	1·94	3·04
Differences between regressions	2	0·0061	0·0031		
Deviation from total regression	289	0·4759			

It may be seen from Table III that males, females and indeterminants do not differ significantly. The data were then pooled and the combined equation was found to be :

$\text{Log } W = -4 \cdot 5721 + 2 \cdot 8397 \text{ Log } L$

and the parabolic equation, $W = 0 \cdot 00002679 \; L^{2 \cdot 8397}$

Similarly the data from samples obtained from the sea for 66 males and 29 females were treated separately and were analysed as described above. No differences were found between the sexes. The common equation was found to be :

$\text{Log } W = -4 \cdot 7427 + 2 \cdot 9075 \text{ Log } L$

and the parabolic equation, $W = 0 \cdot 00001808 \; L^{2 \cdot 9075}$

In view of the above the data on samples obtained from the lagoon and the sea were further analysed by the Analysis of Covariance. The relevant details are given in Tables IV—VI.

TABLE IV

Statistics of length-weight relationship of L. macrolepis *from the sea (Palk Bay) and the lagoon**

Locality	N	SX	SY	SX^2	SY^2	SXY
Sea	97	216·6580	169·8953	485·0281	382·6713	306·9853
Lagoon	293	625·3032	436·0135	1337·3880	938·8840	673·4822

*Notations are same as in Table I.

TABLE V

Regression data of length-weight relationship of L. macrolepis *from the sea (Palk Bay) and the lagoon**

Locality	D.F.	Sums of squares and products			b	Errors of estimate	
		x^2	xy	y^2		D.F.	S.S.
Sea	96	1·1035	3·1953	9·4140	2·8956	95	0·1617
Lagoon	292	2·9030	8·3699	24·6502	2·8832	291	0·5181

*Notations are same as in Table II.

TABLE VI

Test of significance

Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F.	5% F.
Deviation from individual regressions within localities .	386	0·6798	0·0018	9·0	254
Differences between regressions	1	0·0002	0·0002		
Deviation from total regression	387	0·6800			

It may be seen from Table VI that the fish from the sea and the lagoon do not differ significantly. Therefore the length-weight data of fish from the two localities were pooled together and the regression equation was calculated to be :

$\text{Log } W = -4{\cdot}6532 + 2{\cdot}8750 \text{ Log } L$

and the parabolic equation, $W = 0{\cdot}00002222 L^{2{\cdot}8750}$

The observed values of length and weight to which the calculated line has been fitted are shown in Fig. 1.

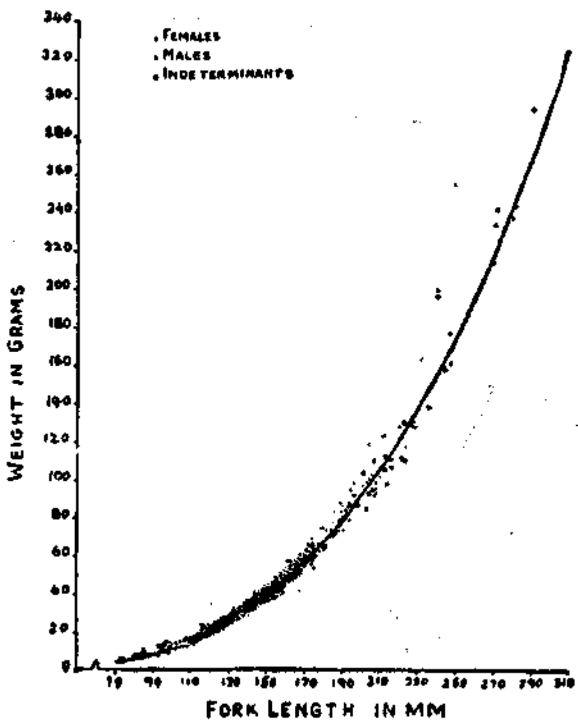

Fig. 1. Length-weight relationship of *Liza macrolepis*.

CONDITION FACTOR

The values of the coefficient of condition have been used widely by fishery investigators to express the relative robustness of the fish, in age and growth studies, to indicate the suitability of an environment for a species, to measure the effect of environmental improvement and the attainment of sexual maturity and spawning.

Le Cren (1951) stressed the superiority of the relative condition factor K*n* over the condition factor *K* and Blackburn (1960) reviewed in detail the methods employed in calculating the K*n* values. The K*n* has been calculated from the formula, $Kn=W/aL^n$; in other words, observed weight divided by the calculated weight.

In the present study both the sexes have been treated together. The K*n* values calculated separately for each fish in the sample have been added up and the mean for each month obtained. The monthly values and the weighted average based on the above values for the entire period of study are given in Table VII.

TABLE VII

Condition factor for Liza macrolepis *from the lagoon*

Month	No. of fish examined	K*n* value	Month	No. of fish examined	K*n* value
1958			1959 (contd.)		
June	33	0.931	May	40	0.961
July	32	0.992	June	25	1.009
August	16	0.905	July	39	0.928
September	43	0.807	August	No Data	
October	29	0.942	September	No Data	
November	17	1.059	October	38	1.032
December	52	1.056	November	19	1.086
			December	32	1.131
1959			1960		
January	29	0.948	January	34	1.060
February	43	0.983	February	32	0.984
March	42	0.979	March	45	0.988
April	43	1.003			
			Weighted average	691	0.975

It may be seen from the Table that the condition factor varied between 0·807 to 1·131. The values were lower than the weighted average in June, August to October 1958, and January, May and July 1959. During the rest of the period the condition factor was higher than the weighted average.

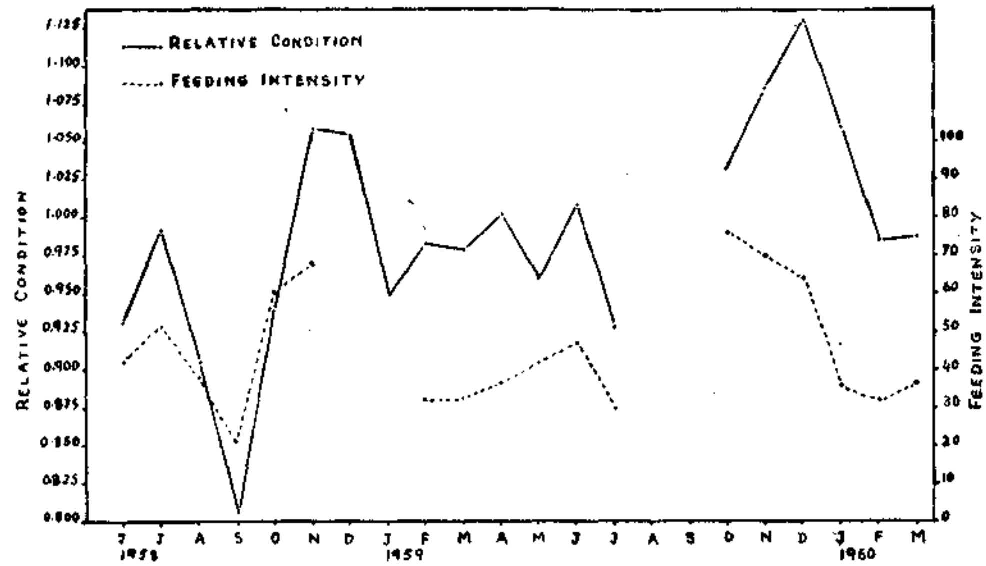

Fig. 2. Fluctuations in the relative condition factor and feeding intensity in *Liza macrolepis*.

The fluctuations in the condition factor and the feeding intensity are shown in Fig. 2. The total points obtained in each month for the stomach contents by the points volumetric method of analysis (Luther, 1962) were divided by the number of fish examined in that month to arrive at the average.

A high feeding intensity was noted during July 1958 compared to the preceding month. But it gradually dropped to a low value in September after which there was a steep rise. Data on this aspect were not available for December 1958 and January 1959. A general low feeding intensity was seen during February to July 1959. Data were not available from August to September due to drought conditions in the lagoon. A high feeding intensity was noted in October 1959, after which the curve shows a gradual decline till December; thereafter, the decline was marked in January 1960, maintaining about the same level during February and March also.

A study of the curves of the K*n* values and the intensity of feeding shows a direct relationship in their fluctuations from June to November 1958. A similar trend could be noted for the period, February to July 1959 also. Although a reverse trend is apparent in the relation during October-December 1959, the intensity of feeding was fairly high during these months after which the relation is direct for the remaining period.

Since the fish available for this study from the lagoon were mostly immature, the variations in the condition factor are evidently not related to maturity cycle.

MATURATION AND SPAWNING

The maturity stages adopted in the present study are given below together with the corresponding maturity scale of the I.C.E.S. (Wood, 1930) for comparison.

Stage	*L. macrolepis* : gonadial condition		Maturity Scale of I.C.E.S.
	Female	Male	
1	2	3	4
I (Immature)	Pinkish occupying ¼ to ½ body cavity. Ova irregular and transparent. Maximum size of ova 0·24 mm.	Whitish, ribbon shaped occupying ½ body cavity.	I—II
II (Maturing I)	Yellowish occupying ½-2/3 body cavity ; ova round, partially yolk-laden. Maximum size of ova 0·37 mm and mode of the largest group of ova at 0·21 mm.	Whitish, occupying 2/3 body cavity.	III
III (Maturing II)	Yellowish, occupying 2/3- ¾ body cavity; ova round and fully laden with yolk. Maximum size of ova 0·54 mm and the mode of the largest group of ova at 0·36 mm.	Whitish, occupying 2/3-¾ body cavity.	IV
IV (Mature)	Yellowish, occupying nearly the entire body cavity with some ova visible to the exterior. Yolk vacuolated, perivitelline space present. Maximum size of ova 0·71 mm and the mode of the largest group of ova at 0·51 mm.	Creamy white occupying the entire body cavity.	V
V (Oozing)	Fish in the oozing stage not available.	Fish in this stage not available	VI
VI (Spent)	Flaccid with blood vessels prominent over the surface, occupying not more than ½ the length of body cavity. Maximum size of ova vary since a few degenerating ova often occur.	Flaccid, occupying about ½ body cavity.	VII

Development of ova to maturity.—To study the maturation of ova, a small portion of the ovary was teased on a microglass slide and the diameters of 100 ova in immature and spent ovaries and 200 ova in maturing and mature ovaries were measured with an ocular micrometer at a magnification of 16·8 μ. The distribution of ova of various size groups in the anterior, middle and posterior parts of the ovary was found to be uniform. The method of measuring ova was as suggested by Clark (1934) and adopted by De Jong (1940), Prabhu (1956) and other workers. Ova measuring 5 micr. div. and above were taken into consideration. In drawing the frequency polygons, the diameter frequencies have been grouped into 2 micr. div. groups as 5-6, 7-8 etc.

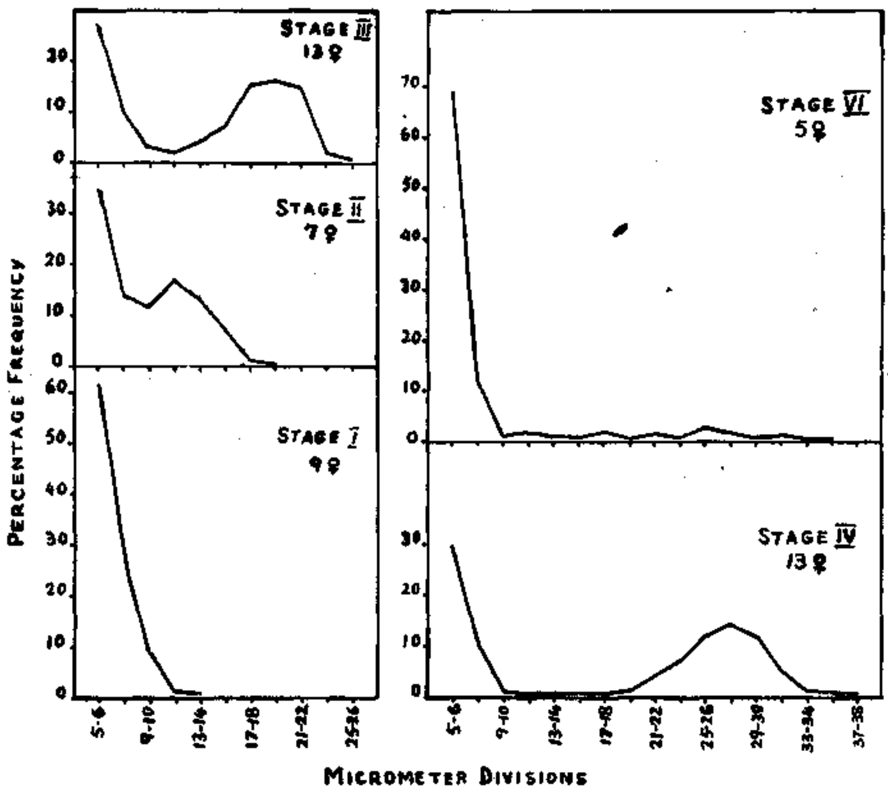

Fig. 3. Ova-diameter frequency polygons of different stages of maturity of *Liza macrolepis*.

Fig. 3 gives the different stages of development of ova in the ovaries. In stage I, the ova are small measuring a maximum of 13 micr. div. Even though there are a few larger ova measuring between 9 and 13 micr. div., withdrawal of a batch of ova from the general egg-stock is not indicated. In stage II, a distinct batch of eggs is separated from the general egg-stock with a mode at 11-12 micr. div. As the ovaries approach stage III, the mode of the maturing group shifts to 19-20 micr. div. In stage IV the mature group of ova is further separated from the immature group with its mode at 27-28 micr. div. Since stage IV is the most advanced stage observed in this study and because the ova diameter frequency polygons of the mature ovaries present only a single well differentiated group of ova, it is inferred that individual fish spawns only once during a short period in a season. This is further supported by the ova diameter frequency polygons of the spent ovary (stage VI), where after spawning only the immature stock of eggs is left with or without a few degenerating ova.

TABLE VIII

Percentage occurrence of maturity stages of L. macrolepis *from the lagoon in different months*

Month	Number of fish examined	Maturity stages					
		I	II	III	IV	V	VI
1958							
July	37	86·49	13·51	..	..	..	..
August	17	17·65	47·06	..	..	..	..
September	49	95·92	..	..	..	..	4·08
October	24	91·67	..	..	..	..	8·33
November	17	64·71	..	..	..	..	35·29
December	53	88·63	5·66	3·77	..	..	1·89
1959							
January	29	96·55	..	..	..	..	3·45
February	86	93·00	2·33	2·33	2·33	..	..
March	55	100·00	..	..	..	..	..
April	42	100·00	..	..	..	..	..
May	40	100·00	..	..	..	..	..
June	25	100·00	..	..	..	..	..
July	49	95·92	4·08	..	..	..	..
August		Data not available					
September		Data not available					
October	39	76·92	5·13	..	5·13	..	12·82
November	12	33·33	8·33	..	8·33	..	50·00
December	38	76·32	7·89	7·89	2·63	..	5·26
1960							
January	65	84·62	4·62	1·54	3·08	..	6·15
February	32	93·75	3·13	..	3·13	..	..
March	82	95·12	4·88	..	..	..	..
April	35	100·00	..	..	..	..	..
May	40	100·00	..	..	..	..	..
June		Data not available					
July	40	92·50	7·50	..	..	..	..
August	50	96·00	4·00	..	..	..	..

Spawning season.—Occurrence of fish in the different stages of maturity in the lagoon is given in Table VIII. From the sea during 1958, all the eight specimens examined in June were in stage VI ; in August out of 17 specimens 5·88% were in stage II, 5·88% in stage III, 35·29% in stage IV and 52·94% in stage VI ; in October out of 25 specimens 84·00% were in stage I, 8·00% in stage II and 8·00% in stage III. During 1959, out of 94 specimens examined in July 7·45% were in stage I, 12·77% in stage II, 22·21% in stage III, 19·15% in stage IV and 40·43% in stage VI ; in August out of 75 fish 13·33% were in stage I, 4·00% n stage II, 40·00% in stage III, 10·67% in stage IV and 32·00% in stage VI ; in September out of 4 specimens examined 25% was in stage III and 75% in stage IV.

The combined data for the lagoon and the sea show the occurrence of maturing, mature and spent fishes during June to February indicating that the fish spawns during this period with a peak during July to August. In this connection it may be mentioned that observations of Chidambaram and Kuriyan (1952) on *Mugil troschelli*, *M. vaigiensis* and *M. seheli* from Krusadai Island (Gulf of Mannar) also show that these species have a prolonged breeding period extending from May to February.

SIZE AT FIRST MATURITY

Fish available during peak period of the breeding season (July-August) were used to determine the size at first maturity (Table IX). Since only large-sized fish were available.

TABLE IX

Occurrence of immature, maturing and mature, and spent L. macrolepis *in each* 10 *mm length group from the sea*

Length group (mm)	Male				Female			
	Total number of fish	stage I	stages II-IV	stage VI	Total number of fish	stage I	stages II-IV	stage VI
120—129	4	4	..	..	1	1	..	..
130—139	8	5	3	..	2	2	..	..
140—149	15	4	5	6	2	..	..	2
150—159	12	3	3	6	2	..	..	2
160—169	8	..	5	3	3	1	..	2
170—179	6	..	4	2	3	..	3	..
180—189	7	..	3	4	1	..	..	1
190—199	6	..	5	1	3	..	1	2
200—209	8	..	7	1	5	..	2	3
210—219	7	..	2	5	2	..	1	1
220—229	8	..	6	2	3	..	2	1
230—239	6	..	3	3	4	..	1	3
240—249	8	..	6	2	2	..	2	..
250—259	1	..	1	..	6	..	2	4
260—269	1	..	1	..	2	..	1	1
270—279					14	..	11	3
280—689					12	..	9	3
290—299					11	..	9	2
300—309					5	..	5	..
310—319					2	..	2	..

during this period which may probably be due to differential fishing it is difficult to demarcate the actual minimum size at first maturity. The smallest female with spent gonads measured 141 mm, while all fish were in the maturing stage and above beyond 170 mm which may be considered as the size at first maturity. The smallest male with maturing gonads measured 136 mm while all fish were in the maturing stage and above beyond 160 mm which may be considered as the size at first maturity for males. As in many other fishes, males seem to attain exual maturity at a smaller size than the females. In *M. parsia* it has been found that males attain sexual maturity at 95-105 mm and females between 105-115 mm (Sarojini, 1957).

SEX RATIO

In *L. macrolepis* sex could be differentiated macroscopically in fish above 100 mm LCF. The two sexes were equally distributed in the fish caught from the lagoon, most of which were immature. However, their ratio in individual samples varied to some extent. The male and female fish available from the sea during the spawning season were in 1.2:1 in ratio. Observations on *M. tade* by Pillay (1954), on *M. parsia* by Sarojini (1957) have also shown that the two sexes were present in more or less equal numbers in the commercial fish catches in Bengal waters.

FECUNDITY

For this study maturing II and mature ovaries were taken into consideration. From an ovary of known weight a small portion was cut out and weighed in a balance. The piece was teased and the ova were spread evenly on a counting chamber. The number of ova in five squares was counted and the total number of ova was computed based on this and the total weight of the ovary. The fecundity of 9 specimens of *L. macrolepis* ranging in size from 220-299 mm is given below :

LCF mm.	Weight of ovary (gm)	Total number of ova
220	7·34	1,51,920
233	19·60	4,30,886
242	10·56	3,88,151
259	15.77	3,86,619
271	23·98	4,85,595
272	24·70	5,20,277
282	36·60	5,24,600
291	32·20	6,76,200
299	11·56	6,48,365

The fecundity varies between 1,51,920 and 6,76,200. Pillay (1954) estimated 90,416 to 3,22,959 in the mature gonads of *M. tade* and Sarojini (1957 and 1958) 2,00,000 to 6,00,000 in *M. parsia* and 14,913 to 56,486 ova in *M. cunnesius*.

AGE AND GROWTH

For the determination of age and growth rate of fishes two methods are generally employed, *viz*., (i) interpretation of seasonal marks on the hard structures such as the otoliths, opercular bones, fin spines and scales, and (ii) analysis of length frequency data. For the present study some observations on the scales and analysis of length frequency data have been made.

Scale study.—Regular markings on scales in the form of 'breaks' useful for age determination in grey mullets have been reported by Jacot (1920), Kesteven (1942), Thomson (1951, 1957), Pillay (1954), Sarojini (1957, 1958) and Broadhead (1958). Examination of the scales of *L. macrolepis* revealed the presence of certain 'breaks' traceable round the scale. The occurrence of these 'breaks' was studied to find out whether they could be useful for the determination of age and growth.

The monthly samples of scales of *L. macrolepis* collected from the lagoon during August, 1958 to March 1960 have been examined. The monthly size range of fish together with the total number of fish examined and the percentage of fish with complete 'breaks' of recent formation are given in Table X. It could be seen from this table that the recently formed

TABLE X

Percentage occurrence of L. macrolepis *with recently formed 'breaks' in scales from the lagoon*

Month	Size range of fish examined in mm	Total number of fish examined	Percentage of fish with 'breaks' at margin of scales
1958			
August	107—256	12	..
September	105—155	32	31·25
October	100—234	13	61·54
November	139—234	7	28·57
December	75—280	24	12·50
1959			
January	71—247	18	11·10
February	106—220	23	4·35
March	86—173	45	20·00
April	104—149	24	12·50
May	88—185	31	29·03
June	85—223	14	..
July	110—193	22	13·64
August	Data not available		
September	Data not available		
October	110—201	30	..
November	137—233	13	..
December	109—240	28	3·33
1960			
January	90—218	28	7·14
February	92—208	12	50·00
March	113—228	12	..

breaks' were noted almost throughout the period, the maximum during the year 1958 being in October whereas its maximum in 1959 was in May, and nil in October and November. The foregoing observations therefore suggest that the formation of 'breaks' in the scales of *L. macrolepis* was not annual. Scales of 85 fish ranging in size from 120 to 302 mm in length collected from sea during July and August, 1959 have also been examined. Of these, only 16 fish ranging in size between 141 and 302 mm had 1-2 complete 'breaks'. It has also been found that the number of 'breaks' in the scales had no relation to the size of the fish. The foregoing observations indicate that the 'breaks' in scales of this species from this area are not useful for age determination studies.

The smallest fish with recently formed 'breaks' was 86 mm in length. The minimum size at first maturity was found to be 160 mm for males and 170 mm for females of this species. Hence the 'breaks' observed in scales could not even be considered as spawning marks.

Devasundaram (1952) observed that the 'breaks' or linea on the scales of *M. cephalus* were highly irregular in respect of time and manner of formation and consequently could not be employed for age and growth determination. In a study of tagging of mullets Jhingran and Jena (1964) state that "there do not appear to be any clear enough markings suggestive of being considered as annuli on the scales of *L. troschelli*".

In *L. macrolepis* the highest percentage (61%) of fish with recently formed 'breaks' in scales was observed in October 1958 immediately following a period of low feeding intensity as well as a low condition (Fig. 2). Similarly the occurrence of a high percentage (50%) of such fish seems to be related to a low feeding intensity and poor condition during January 1960. Therefore it is possible that the 'breaks' are formed in scales during times of low feeding intensity and poor condition.

Length-frequency distribution.—The monthly length measurements were classified into size groups with a class interval of 20 mm and the percentage frequencies calculated except when the total number of fish was less than 25 in any month. For a class interval of 60-79 mm, 70 mm was taken as representing the mid point ; for 80-99 mm size group 90 mm and so on. The length frequency curves for the period from June 1958 to December 1960 are shown in Fig. 4. The samples of fish obtained from the lagoon during the three years of study ranged in size between a minimum of 68 mm and a maximum of 282 mm. It may be seen that in most of the curves, a single prominent mode is formed at 110, 130 or 150 mm in different months. However, during the greater part of the year, the modes are at 110 and 130 mm. This may indicate that the fish in the lagoon belong to a particular group, the age of which could not be determined for reasons obvious, and after entering the lagoon do not show much growth for reasons not very clear. Length frequency studies, therefore, did not yield useful results in determining the age and growth of the species.

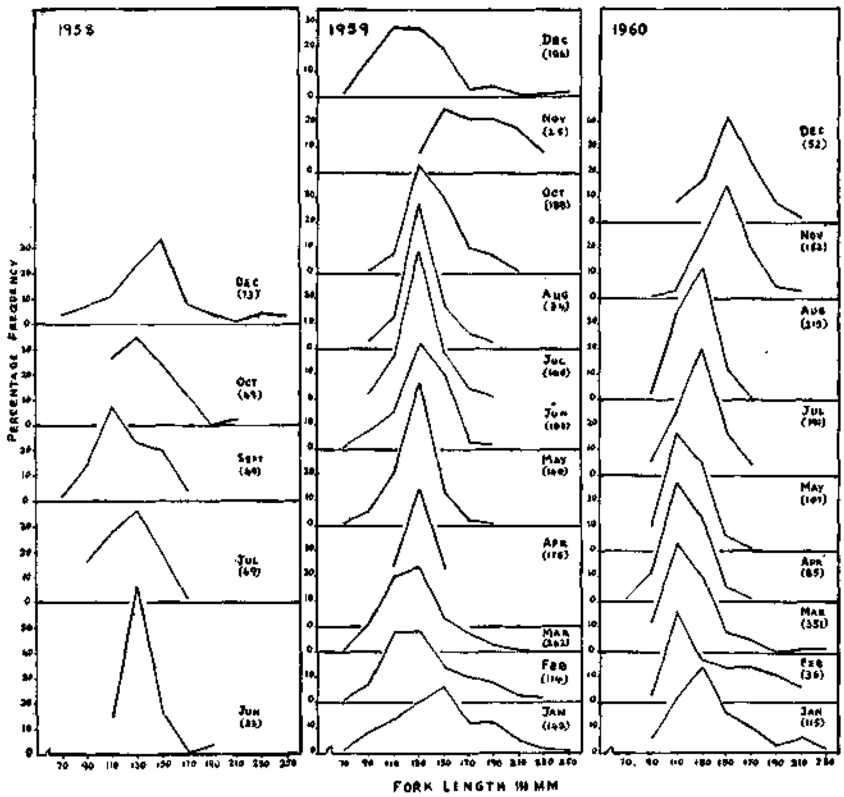

Fig. 4. Length-frequency curves for *Liza macrolepis* from lagoon.

The continuous occurrence of the same modes in the length frequency curves particularly during March-July/August may probably be due to (i) the selectivity of the gear *Kannivalai* and method of capture; (ii) the prolonged breeding habit of the species and (iii) the bar formation resulting in drastic changes in the physico-chemical characteristics of the water in the lagoon, and the food and space available for the fish resulting in retardation of growth.

John (1948) has observed differences in the rates of growth of mullets in aquarium tank, culture tank and the open lake, faster rate of growth having been observed in the open lake than in the other two types of environment. He concluded that growth is retarded in captivity and that environment more than food plays an important part in determining their rate of growth.

Yashauv as cited by Hickling (1962) states that overcrowding in carp culture results in retarded growth. Kawamoto *et al.* as cited by Hickling (1962) are of the opinion that the presence of large quantities of waste products of fish in the form of ammonium nitrogen in the densely stocked ponds is inhibitory to growth. Kawamoto as cited by Hickling (1962) also suggests that frequent disturbances caused to fish due to fishing brings about retarded growth in fishes since they have to expend extra energy for mere maintenance, which could otherwise be utilised for growth.

The fairly low K*n* values obtained for the fish from the lagoon during summer months may reflect the unfavourable conditions that exist in the lagoon causing retarded growth in the present case.

Length-frequency distribution of fish from the sea.—The length-frequency distributions of fish from the sea (Palk Bay) during June to August 1958 and July-August 1959 which coincide with their peak breeding season are plotted in Fig. 5. During 1958 three modes at 110 mm,

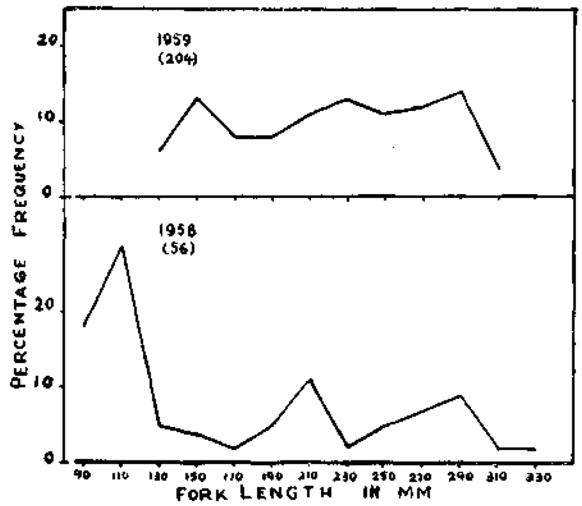

Fig. 5. Length-frequency curves for *Liza macrolepis* from the sea.

210 mm, and 290 mm, and in the 1959 season three modes at 150 mm, 230 mm and 290 mm, could be observed. If these three modes represent the size at the end of first, second and third year, combining the data, the average size may be stated as 130 mm, 220 mm and 290 mm respectively.

PARASITES

A single larval nematode of the genus *Anisakis* was observed in the body cavity of a single fish of 130 mm.

II. *Mugil cephalus* Linnaeus

The length-weight relationship, condition factor, age and growth, parasites and method of fishing have been studied for this species. The methods employed for the different aspects of the study were the same as those for *L. macrolepis*. The present account is based on fish collected from the lagoon.

LENGTH-WEIGHT RELATIONSHIP

A total number of 422 fish ranging in size from 77 mm to 302 mm was examined. All the fish were immature and both the sexes have been combined for the study. The length weight relationship was calculated by the method of least squares which is represented by the equations :

$$\text{Log } W = -4 \cdot 9789 + 3 \cdot 0274 \text{ Log } L$$

$$W = 0 \cdot 00001050 \quad L^{3 \cdot 0274}$$

The observed values of length and weight to which the calculated line has been fitted are shown in Fig. 6.

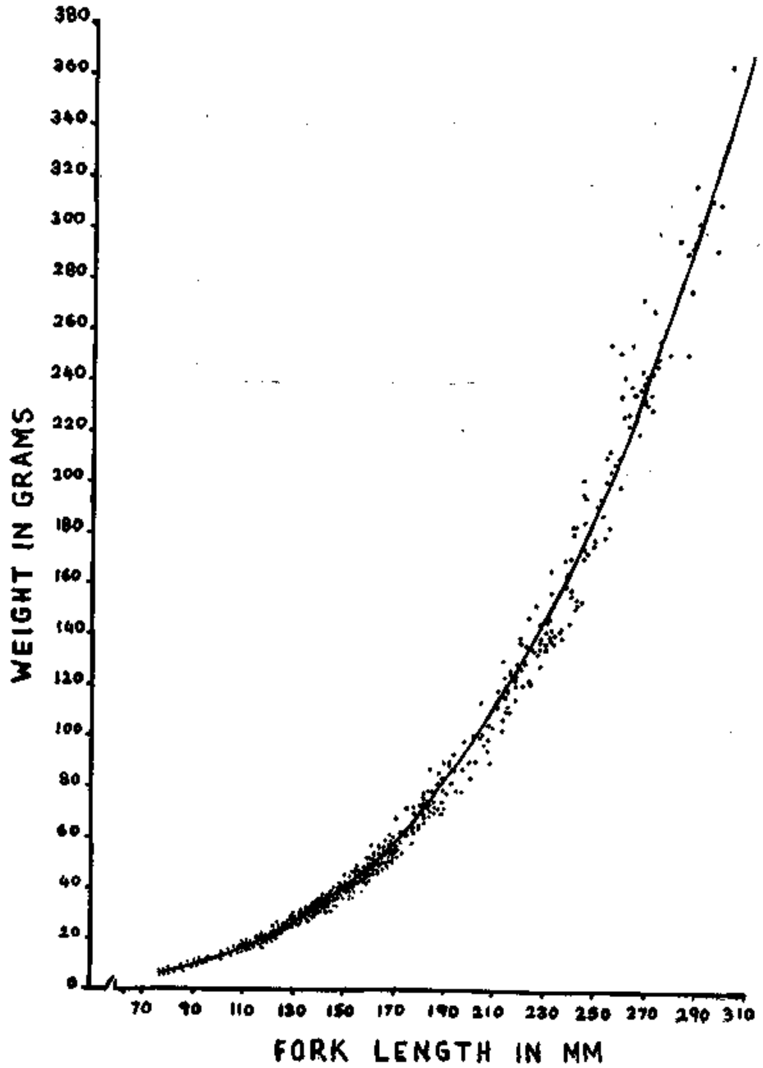

Fig. 6.—Length-weight relationship of *Mugil cephalus*.

CONDITION FACTOR

The monthly K*n* values and the weighted average for the entire period of study are given in Table XI. It may be seen from the table that the condition factor varied between 0·875

TABLE XI

Condition factor for Mugil cephalus *from the lagoon*

Month	No. of fish examined	K*n* value	Month	No. of fish examined	K*n* value
1958			1959 (contd.)		
April	14	1.101	April	37	1.046
May	31	1.025	May	36	0.963
June	45	0.903	June	14	0.941
July	32	0.933	July	43	0.935
August	52	0.899	August	No Data	
September	36	0.876	September	No Data	
October	9	0.926	October	18	0.989
November	15	0.875	November	30	1.016
December	30	0.961	December	15	1.032
1959			1960		
January	24	1.042	January	31	1.027
February	34	0.973	February	13	1.059
March	49	1.017	March	47	1.002
			Weighted average	655	0.971

and 1·101. The values were lower than the weighted average from June to December 1958 and from May to July 1959. During the rest of the period the condition factor was higher than the weighted average.

The fluctuations in the condition factor and the feeding intensity are shown in Fig. 7. The high feeding intensity seen in April 1958 dropped to a low value in June. With a slight rise in July the feeding intensity dropped low again in August. It increased through September

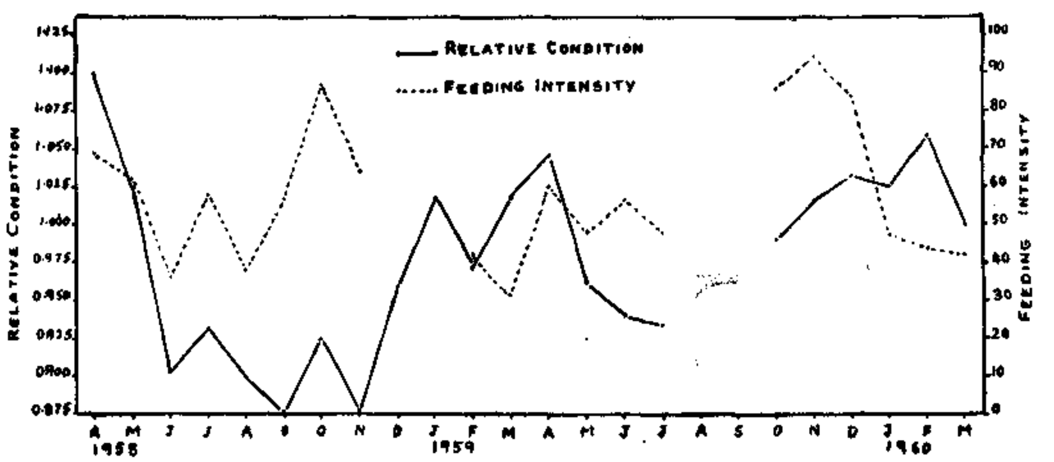

Fig. 7—Fluctuations in the relative condition factor and feeding intensity in *Mugil cephalus*.

reaching a high value in October. A slight drop is evident in November. From the fairly low values noted in February and March 1959 the feeding intensity increased in April. Thereafter, the value fluctuated at a lower level till July.

A study of the curves of the K*n* values and the feeding intensity from April to November 1958 shows some relation between the two. Thereafter the relation between the two is not clear. This may, therefore, indicate that feeding may not be related to condition factor of the fish.

Since all the fish available for this study were immature, the fluctuations in the condition factor are obviously not related to maturity cycle.

AGE AND GROWTH

For this study some observations on the scales and analysis of length frequency data have been made.

Scale study : An examination of the scales of *M. cephalus* revealed the presence of certain 'breaks' traceable round the scale. The percentage occurrence of fish with recently formed 'breaks' in the scales, the size range and number of fish examined in each month are given in Table XII. It could be seen from this table that the recently formed 'breaks' were noted

TABLE XII

Percentage occurrence of M. cephalus *with recently formed 'breaks' in scales from the lagoon*

Month	Size range of fish examined in mm	Total number of fish examined	Percentage of fish with 'breaks' at margin
1958			
August	140—201	13	38·46
September	137—243	33	24·24
October	197—240	5	40·00
November	205—261	5	20·00
December	216—288	15	60·00
1959			
January	184—295	9	88·89
February	96—276	14	7·14
March	109—246	35	8·57
April	116—179	32	6·25
May	101—172	28	..
June	Data not available		
July	127—186	32	3·13
August	Data not available		
September	Data not available		
October	132—239	18	..
November	168—298	30	3·33
December	175—302	15	6·67
1960			
January	193—290	31	3.23

almost throughout the period. A high percentage of such 'breaks' was noted in December 1958 (60%) and January 1959 (88.87%), their occurrence during December 1959 and January 1960 being 6.67% and 3.23% respectively. The foregoing observations suggest that as in the case of *L. macrolepis*, the formation of 'breaks' in scales of *M. cephalus* was not annual. It has also been found that the number of 'breaks' in a scale had no relation to the size of the fish. Therefore the 'breaks' on the scales of this species from this area are not useful for age determination studies.

In *M. cephalus* the highest percentage (60-89%) of recently formed 'breaks' was noticed during December 1958 and January 1959 following a period of prolonged low condition during June to November 1958 (Fig. 7). In *M. cephalus* therefore low condition factor may effect the formation of 'breaks' in the scales.

Length-frequency distribution : The length frequency curves for the period from May 1958 to December 1960 are shown in Fig. 8. From the curves for 1958, it is seen that the mode at 150 mm in May remained stationary in June. Thereafter the mode progressed showing an increment of 20 mm each month till August at 190 mm. The mode is not distinct in September. The mode at 230 mm in November, shifted to 250 mm in December. These size groups can be traced further during February and March 1959 with modes at 250 and 260 mm respectively.

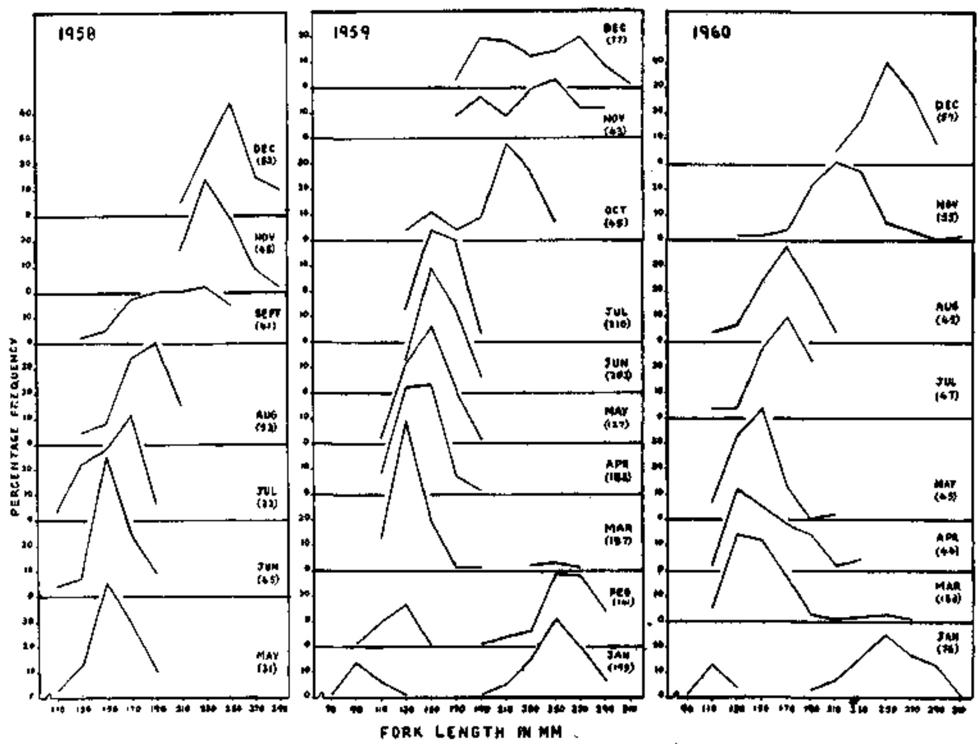

Fig. 8—Length-frequency curves for *Mugil cephalus* from lagoon.

The mode at 90 mm in January 1959 shifted to 130 mm in February. No progress in the mode is seen in March but the mode shifted to 150 mm in April. From April to July the mode remained stationary. Due to drought conditions no sample was available in August and September. In October a small mode at 150 mm and a prominent mode at 210 mm are seen. The latter shifted to 250 mm in November and 270 mm in December. The smaller mode at 150 mm in October shifted to 190 mm in November and remained stationary in December. Thus a faster period of growth during January to February alternated with a slow period of growth during March to July which coincides with the period of isolation of the lagoon from the sea followed by a faster period of growth during October to December. Between January and February 1959, a duration of one month, a growth increment of 40 mm is seen and during October to December, an increment of 60 mm is noted during a period of 2 months while during March to July, a period of 4 months, a growth increment of 20mm is seen. The foregoing observations indicate that growth is retarded during the period when the lagoon is isolated from the sea during summer.

The mode at 110 mm in January 1960 shifted to 130 mm in March. No progress in the mode is seen in April. The mode formed at 150 mm in May progressed to 170 mm in July but no further progress is seen in August. Thus from March to August, a period of 5 months, a growth increment of 40 mm is seen. Samples were not available in September and October due to drought conditions. During November to December a growth increment of 40 mm is noted. During this year also, the slow growth rate is noted during the period of isolation of the lagoon.

Summarising the above observations, the mode at 150 mm in May 1958 shifted to 260 mm in February 1959 showing a growth increment of 110 mm during a period of 9 months, *i.e.* 12 mm in a month and 144 mm during a period of 12 months. The progression of mode at 90 mm in January 1959 to 250 mm in January 1960 shows a growth increment of 160 mm during a period of 12 months. The progression of the mode at 110 mm in January 1960 to 250 mm in December shows a growth increment of 140 mm during a period of 11 months, *i.e.* about 152 mm in 12 months. From the above it may be said that on an average a growth increment of 152 mm is attained in one year. Similar trends of growth have been observed in *M. cephalus* by Kesteven (1942) and Broadhead (1958).

As mature specimens were not met with either in the lagoon or in the inshore catches the spawning period of *M. cephalus* in this area is not known. The occurrence of mature and spent specimens of *L. macrolepis* and the absence of such specimens of *M. cephalus* in the inshore catches indicate the probability of offshore spawning of the latter. Jhingran (1958) has observed sea-ward migration of mature *M. cephalus* in October from Chilka Lake and Anderson (1958) has authentically reported the offshore spawning habit of *M. cephalus*. During the course of the present study young ones were noticed in the fishery only in January, indicating that the spawning period is brief in *M. cephalus*.

PARASITES

Specimens of *M. cephalus* ranging in size between 105 and 298 mm collected from the lagoon during April 1959 to May 1960 were found to be infested by the larvae of the nematode *Anisakis* sp. The larvae were seen free in the body cavity all over the viscera, and also embedded in a coiled form in the liver, kidney and in the tissue all along the ventral surface of the trunk vertebrae. The parasite was invariably present in every sample of fish examined with a maximum number of 12 in a fish. The rate of infestation varied from 20 to 50% of the fish in different samples. The very rare occurrence of the nematode in *L. macrolepis*, as noted earlier, collected from the same locality and its very common occurrence in *M. cephalus* suggests that the latter is highly susceptible for attack by nematodes.

NOTES ON THE FISHERY OF GREY MULLETS NEAR MANDAPAM

1. Fishing Methods

The main gear employed for the capture of mullets near Mandapam are *Kannivalai* or *Kannikavalai*, *Veechuvalai* (cast net) and *Viduvalai*.

Kannivalai or Kannikavalai : *Kannivalai* is also known as *Sippivalai* (Fig. 9). A brief description of the net was given by Tampi (1959). It is a rectangular net of about 75 metres long and 1.5 metres wide with a mesh size of 3 cm from knot to knot. To the head line which is 3 mm thick are attached wooden floats of 40×30 mm size at intervals of about 25 cm. One wooden peg of 30 cm length is tied at either end of the head line. A strip of net 10-15 cm wide with a mesh size of 15 mm is attached at the bottom to act as foot rope and keep the net vertical in water. Two men operate the net. Each fisherman pays out the net as they go away from each other in waist to knee deep water. Either end of the net is coiled inwards and the wooden peg is driven into the ground to form a kind of trap near which the men squat in water. The net is generally laid opposite the direction of movement of the fish. The fish approaching the net and finding the obstruction in front move sidewards along the net and finally reach the trap from where the fishermen deftly catch them by their head.

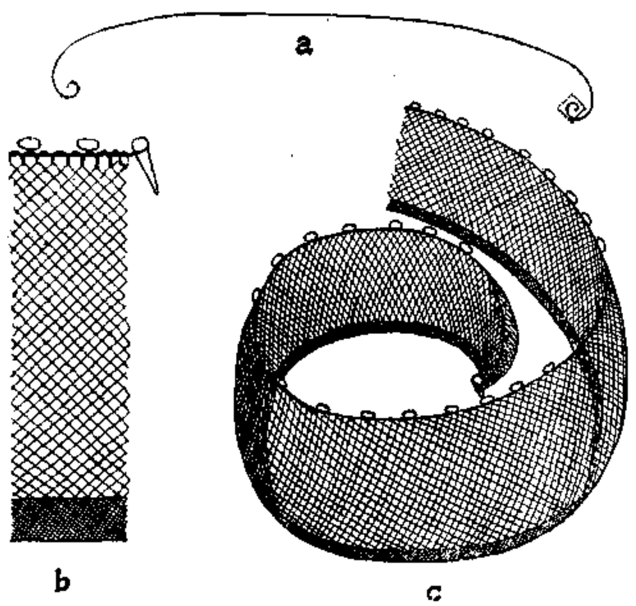

Fig. 9—Diagramatic sketch of *Kannivalai*: (a) aerial view of the net when cast; (b) one end portion of the net; (c) loop forming the trap.

The net is operated in the lagoon with fairly good catches. *Kannivalai* is efficient for fishing when the water is calm and clear since rough weather conditions keep the bottom portion of the net off the ground thus allowing the fish cross the net underneath, and turbid waters afford poor visibility to catch the fish. For this reason, poor catches are obtained in the lagoon during October to December which are the monsoon months in the area.

Veechuvalai : *Veechuvalai* without the central cord for hauling are employed both in the lagoon and in the foreshore areas of the sea.

Viduvalai : The net, operated in the sea, is similar to the *Iriavalai* described by Hornell (1927) except for its smaller size and difference in mode of operation. The net takes a trapezoid bag form when spread on the ground. It measures about 20 metres across the mouth and 6 metres at the opposite side, the bag portion being 6 metres long. The mesh is 3.5 cm wide and uniform throughout. About 40 floats of $10 \times 6 \times 1.5$ cm size are attached 50 cm apart along the head rope which is 20 metres long and 1.0 cm thick. The length of the rope between the head rope and the ground rope, without floats, is about 3 metres long. The ground rope is 14 metres long and 0.5 cm. thick.

Two persons are essential to operate the net; often a third person is also included for assistance. To set the net, one end of the ground rope and a part of the bag portion is carried by one person into neck deep water where he releases the net and holds the end of the ground rope under foot while the second man remaining in waist deep water nearer the shore holds the other end of the ground rope tightly pulled under foot. The head rope is set free to float, when the net assumes a hemispherical shape.

The appearance of the mullet in the inshore areas of the sea is awaited by fishermen from elevated places along the beach. Movement of mullets is recognised by the dark patch and the characteristic ripples they cause on the surface. On sighting the fish, the net is set against their direction of movement. As soon as the mullets enter the net, the bottom rope is lifted, both the bottom and head ropes are drawn together and the mouth of the net is rapidly closed trapping the fish. The third person comes into action at the shoreward end of the net for pulling the head rope to close the net.

The net cannot be operated in deeper water since the men operating the net are required to stand still lest the fish might get frightened. For a successful fishing operation the direction of the wind and of the movement of fish should be the same. This requisite facilitates the maximum spread of the head rope and entry of the fish into the net.

2. Composition of the catches

The lagoon at Mandapam is the main source for mullets in the area. However, small quantities are also caught along the sea coast. Tampi (1959) estimated the total catch of fish and prawns for 1958 in the lagoon at 20 metric tons. Mullets comprise nearly 60% of the total catch. The fish are mostly consumed fresh. The fishing season is usually from January to July and from end of October to December in the lagoon ; during August to early October fishing is suspended due to drought conditions. *Kannikavalai* is employed exclusively for catching mullets in the lagoon, cast net being used only rarely. Mullets ranging in size from 7 to 31 cm are caught. The monthly length frequency curves indicate the size composition of *M. cephalus* and *L. macrolepis* available from the lagoon. Besides these, *L. parsia* and *L. tade* are also caught. The general trend of occurrence of the different size groups of the above two species is about the same as for *L. macrolepis*. During November to January when the lagoon is flooded with fresh water, *M. cunnesius* ranging in size from 10-19 cm are caught. *Valamugil seheli*, *V. buchanani* and *Ellochelon vaigiensis* are also caught occasionally in the lagoon.

From the size composition of the catches from the lagoon it is seen that 13 to 15 cm size group was dominant in case of *L. macrolepis* during most part of the year, larger size groups forming only an insignificant portion. The maximum size of fish collected was 282 mm. In *M. cephalus* the dominant size groups vary in different months with modes between 90 and 270 mm. It has been stated earlier that males of *L. macrolepis* attain sexual maturity at about 160 mm and females at about 170 mm. In the present study *M. cephalus* of 295 mm length were immature, but according to Kesteven (1942) it is known to attain sexual maturity at about 27·5 cm (LCF) in males and 29.0 cm (LCF) in females in Australia, and according to Broad head (1953) at an average length of 26.3 cm (LCF) in males and 27·6 cm (LCF) in females in Florida. The foregoing observations therefore suggest that *L. macrolepis* and *M. cephalus* do not enter the lagoon in large numbers after attaining maturity.

Although cast nets are commonly employed to catch mullets close to the shore, only the *Viduvalai* catches are relatively better. The *Viduvalai* is operated in the sea during June to August when large sized mullets with roe and spent gonads occur in the inshore water. *Valamugil seheli* of 30-45 cm, *V. buchananai* of 20-30 cm, *L. macrolepis*, *L. parsia* and *L. tade* of 12-31 cm size, and occasionally *M. cunnesius* of 15-20 cm size are generally caught.

Fry and fingerlings of mullet are available in the creeks along the coast throughout the year, June to December being the period of their abundance.

SUMMARY

Some observations on the biology of the grey mullets, *Liza macrolepis* (Smith) and *Mugil cephalus* Linnaeus from Palk Bay and the lagoon near Mandapam have been made during the period, April 1958 to December 1960.

The length-weight relationship of *L. macrolepis* has been found to be $W=0.0002222 L^{2.8750}$ and that of *M. cephalus*. $W=0.00001050 L^{3.0274}$.

The fluctuations in the relative condition factor have been studied for both the species.

Males and females of *L. macrolepis* attain sexual maturity at about 160 mm and 170 mm. respectively. Individual fish seem to spawn only once in a season, the spawning period extending from June to February with a peak during July and August. The sexes were equally distributed. The fecundity has been found to vary between 1,51,920 and 6,76,200 ova.

The 'breaks' observed in scales of both the species have not been useful in the determination of age and growth. In general, poor 'condition' appears to be the cause for the formation of 'breaks' in scales in both the species.

The growth rate of *M. cephalus*, while immature, computed from length-frequency curves, was found to be 152 mm during a period of 12 months on an average.

Of the two species, *M. cephalus* seems to be highly susceptible for attack by nematode of the genus *Anisakis*.

The fishing methods for the mullets in the lagoon and the sea (Palk Bay) near Mandapam are described. The fishery is supported by immature fish in the lagoon which is the main source of mullets in the area.

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REFERENCES

Anderson, William W. 1958. Larval development, growth, and spawning of striped mullet (*Mugil cephalus*) along the south Atlantic coast of the United States. *U. S. Fish and Wildlife Service, Fish Bull.* **144**, : 501-519.

Blackburn, M. 1960. A Study of condition (Weight for length) of Australian Barracouta, *Thyrsites atun* (Euphrasen) *Aust. J. mar. freshw. Res.* **11** (1) : 14-41.

Broadhead, Gordon C. 1953. Investigations of the black mullet *Mugil cephalus* L., in north-west Florida. *Tech Ser. Fla. Bd. Conserv.*, **7** : 1-34.

1958 Growth of the black mullet *Mugil cephalus* L., in west and north-west Florida. *Mech. Ser. Fla. Bd. Conserv.*, **25** : 1-31.

Chidambaram, K. and G. K. Kuriyan 1952. Notes on the Grey Mullets (*Mugil* spp) of Krusadai Island Gulf of Mannar. *J. Bombay nat. Hist. Soc.*, **50** (3) : 515-19.

Clark, F. N. 1934. Maturity of the California sardine (*Sardina caerulea*) determined by ova diameter mesurements. *Califernia Fish & Game Fish. Bull.*, **10** : 1-51.

De Jong, J. K. 1940. A preliminary investigation of the spawning habits of some fishes of the Java Sea. *Treulia* **17** : 307-30.

Devasundaram, M. P. 1952. Scale study of *Mugil cephalus* Linn. of Chilka Lake. *J. Madras Univ.*, **22** (B) 147-63.

Hickling, C. F. 1962. *Fish Culture.* Febar and Faber, 24 Russel Square London.

Hornell, J. 1927. Fishing methods of the Madras Presidency, Pt. I, Coromandel Coast. *Madras Fish. Bull.* **18** : 96.

Jacot, A. P. 1920. Age, growth and scale characters of the mullets, *M. cephalus and M. curema. Trans. Amer. Micro. Soc.* **39** : 199—299.

Jhingran, V. G. 1958. Observations on the seaward migration of *Mugil cephalus* Linnaeus from the Chilka Lake for breeding. *Curr. Sci.* **27** (5) : 181—182.

Jhingran, V. G. and S. Jena 1964. Recovery of a tagged mullet *Liza troschelli* (Bleeker), about a year after tagging in Chilka Lake, India. *Sci. and Cult.*, **30** : 465—466.

John, C. C. 1948. *Progress Report of the Fisheries Development Scheme,* Central Research Institute, Travancore University, Trivandrum.

Kesteven, G. L. 1942. Studies in the biology of the Australian mullet. I Account of the fishery and preliminary statement of the biology of *M. dobula* Gunther. *Coun. Sci. Ind. Res.* Bull. No. **157**.

Le Cren, E. D. 1951. The length—weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *J. Anim. Ecol.*, 20 : 201—19.

Luther, G. 1962. The food habits of *Liza macrolepis* (Smith) and *Mugil cephalus* Linnaeus (Mugilidae). *Indian J. Fish.* **9**(2, A) : 604-626.

——. 1964. On the shedding of gill raker processes in grey mullets. *J. Mar. biol. Ass. India.* **6**(2): 251-256.

Pillai, V. K. 1955. Observations on the ionic composition of blue-green Algae growing in saline lagoons, *Proc. nat. Inst. Sci. India.* **21** (2) : 90—102.

Pillay, T. V. R. 1955. The biology of the grey mullet, *Mugil tade* Forskal. *Proc. nat. Inst. Sci. India.*, **20** : 187—217.

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

Sarojini, K. K. 1957. Biology and fisheries of the grey mullets of Bengal I. Biology of *Mugil parsia* Hamilton *Indian J. Fish.*, **4** : 160—207.

——1958. Biology and fisheries of the grey mullets of Bengal, II. Biology of *Mugil cunnesius* Valenciennes, *Indian J. Fish.*, **5** : 56-76.

Tampi, P. R. S. 1959. The ecological and fisheries characteristics of a salt water lagoon near Mandapam. *J. Mar. biol. Ass. India* **1** (2) : 113-130.

Thomson, J. M. 1951. Growth and habits of the sea mullet, *Mugil dobula*, in Western Australia. *Aust. J. mar. freshw. Res.*, 2(2) : 193-225.

——1957. Interpretation of scales of the yellow-eyed mullet, *Aldrichetta forsteri* (Cuvier and Valenciennes (Mugilidae) *Aust. J. mar. freshw. Res.*, **8** (1) : 14-28.

Wood, H. 1930 Scottish herring shoals. Pre-spawning and spawning movements. *Scotland Fish. Bd. S. Invest.*, No. 1 : 1—71.