THE FOOD HABITS OF *LIZA MACROLEPIS* (SMITH) AND *MUGIL CEPHALUS* LINNAEUS (MUGILIDAE)

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INTRODUCTION

ACCOUNTS of the diverse views expressed on the food of the grey mullets by various authors have been discussed in the works of Sarojini (1951), Pillay (1953) and Thomson (1954). The grey mullets have been described as plankton feeders, herbivores, omnivores, slime feeders, foul feeders, bottom feeders, etc. Despite the extensive records on the subject, in this group of fishes, there are very few accounts based on studies for an extended period of time in respect of different size-groups from different environs.

So far there is no comprehensive study made on the biology of the grey mullets of the Palk Bay and the Gulf of Mannar. Knowledge of the different habits of this group of fishes, besides being advantageous in the proper exploitation of the resource, will prove helpful in fish-farming practices. Hence, studies on some aspects of fishery and biology of two of the common mullets, *viz.*, *Liza macrolepis* (Smith) and *Mugil cephalus* Linnaeus around Mandapam have been made. The following account deals with the food habits at various growth stages in the two species for an almost continuous period of two years.

ENVIRONMENT, MATERIAL AND METHODS OF STUDY

The grey mullets support a good fishery in the Pullamadam lagoon near Mandapam (09° 17′ N and 79° 06′ E) from January to July and from October to December. The ecological and fisheries characteristics of this lagoon have been studied by Tampi (1959).

L. macrolepis obtained for this study consisted of 631 specimens ranging from 72 to 282 mm. in length (LCF), collected from the lagoon during June 1958 to March 1960. They were mostly in immature and spent recovering and rarely in Stages III and IV. 100 Specimens ranging from 120 to 317 mm. (LCF) in different stages of maturity were obtained during July to August 1959 from Palk Bay and also 183 fry and fingerlings, ranging from 14 to 48 mm. in total length, from creeks during April, May and September 1958.

Of *M. cephalus*, 516 specimens from 78 to 298 mm. (LCF), all in immature stages (I–II), obtained from lagoon during April 1958 to March 1960, 50 specimens (immature) between 155 and 238 mm. (LCF) collected from Palk Bay during May and July 1959, and 9 specimens between 23 and 29 mm. in total length procured from creeks during July 1958, formed the material for study. All the samples of fish were preserved on the field in 5% formalin.

The stomach contents were washed into a petri dish and analysed by points (volumetric) method (Pillay, 1952), taking into consideration the extent of the feed which was determined by the distension of the stomach and the amount of food contained. In the method employed in this study, the condition of feed is expressed as gorged, full, three-fourth-full, half full, quarter full, trace and empty with each being assigned 100, 80, 60, 40, 20, 10 and 0 points respectively. Separate points were allotted for each item of food based on its relative volume. From the values obtained for individual fish, monthly averages were computed and percentages calculated. The 'Index of Preponderance', which aids in grading the gut contents thereby providing indication of the food preferences of the fish, was constructed from volume and occurrence indices as proposed by Natarajan and Jhingran (1961). The volume index, which is the percentage of volume of each food item, was calculated from the total points of all the items over the whole period. The occurrence index of each item was also calculated similarly. Fishes with stomachs gorged, full and three-fourth full, were considered to have been feeding actively. Similarly, stomachs in quarter full, trace and empty conditions of feed were considered to denote reduced feeding activit . The monthly percentage occurrence of the stomachs in active and reduced feeding conditions were utilized to determine the seasonal fluctuations in feeding intensity. The percentage occurrence of the stomachs in the different conditions of feed over the whole period was calculated from the totals for the whole period. In the present study gonads in Stages III to V (I.C.F.E.S.) are considered to be maturing.

The analysed data showed that the stomachs of both the species of mullet could be separated into two types based on the nature of their contents:

Type A—Fish with stomach contents predominated by decayed organic matter and foraminifera.

Type B—Fish with stomach contents formed virtually of gill raker processes of grey mullets.*

* Gill raker processes are those structures present in a double row in the inner surface of the gill rakers. The shedding of these processes in grey mullets will be dealt with separately elsewhere.

The stomachs with gill raker processes can generally be differentiated from the other type of stomachs even without cutting them open on account of their pale yellow colouration and the shrinking of their cardiac portion in the formalin-preserved specimens. The inner lining of the pyloric portion presents many folds, which easily split length-wise into coarse strips and get detached from the rest of the inner wall while pipetting out the contents; the inner lining of the cardiac portion also gets peeled off easily.

When the analyses of the stomach contents of *M. cephalus* obtained from the lagoon were carried out, treating the two types of stomachs together, the percentage composition of the different items appeared to be much diminished in the total averages of their volumetric composition, contrary to the general impression obtained during the course of examination of Type A and Type B stomachs. The gill raker processes formed 87·14% of the contents of type B stomachs, whereas in the combined analysis they formed only 15·79% of the total contents. The percentage composition of decayed organic matter, foraminifera and sand also gave a similar picture (Table I). That the gill raker processes form part of the stomach contents is not hitherto

TABLE I

Comparison of the analyses of the percentage composition of food items from the differentiated (Type A, B) and undifferentiated stomachs of Mugil cephalus *(Lagoon Environment)*

Nature of stomach contents	Decayed organic matter	Foraminifera	Algae	Diatoms	Copepods	Gill raker processes	Sand and spicules
Fish with stomach contents predominated by decayed organic matter and foraminifera [A type stomachs (335)*]	21·66	22·45	4·23	3·92	0·21	..	47·53
Fish with stomach contents virtually with gill raker processes [B type stomachs (181)*]	0·02	0·88	..	0·37	2·12	87·14	9·47
Stomachs not differentiated as above but treated composite (516)*	17·73	18·54	3·46	3·28	0·56	15·79	40·64

* The figures in brackets denote the number of fish examined.

known in mullets. To facilitate comparison of the present results with those of other workers and also to throw light on the significance of this food item in about 35% of the fish examined, it was considered desirable to treat the data obtained from the two groups of stomachs separately. The same procedure was followed for *L. macrolepis* obtained from the lagoon. However, such a differential treatment was not attempted in the analyses of the stomach contents of fish obtained from sea, since stomachs of type B were quite negligible. The broken appendages of crustacea, which were rarely encountered in the analysis in very minute quantities and during summer months only, were treated as forming part of decayed organic matter for the sake of convenience in allotting whole points for each food item.

Food Habits

1. (*a*) Liza macrolepis *from Lagoon Environment—Type A Stomachs*

These formed 63·87% of the total stomachs examined (Table II). The 'Index of Preponderance' of food items with rankings in brackets is presented in Table III, a perusal of which makes it evident that decayed organic matter and foraminifera form the main food, supplemented by diatoms, algae and occasionally by copepods.

The decayed organic matter consisted mainly of a mass of unidentifiable matter. Pillai (1955) has observed that algal growth decreases with the rise in salinity in the lagoon and that beyond a chloride concentration of 1,700 mM. the algae begin to die and disintegrate. The decayed organic matter under discussion is comparable to the decaying 'biological complex' (Tampi, 1959) known to develop at the bottom of the shallow areas of the lagoon.

Foraminifera belonging to 10 genera were identified. Of these, *Operculina*, *Anomalina*, *Elphidium*, *Rotalia*, *Quinqueloculina*, *Triloculina* and *Epinoides* formed the important genera in the stomach contents. *Spiroloculina*, *Lagena* and *Spirillina* were also noticed. Besides these, there were other minor forms which were unidentifiable.

Blue-green algae, *viz.*, *Chroococcus*, *Phormidium*, *Microcoleus*, *Trichodesmium*, *Lyngbya*, *Spirulina*, *Aphanothece* and algal spores were observed in the stomach contents.

Several species of diatoms belonging to 10 genera have been observed. Of these, *Pleurosigma*, *Navicula* and *Nitzschia* formed the most important genera. *Grammatophora*, *Diploneis*, *Pinnularia*, *Cymbella*, *Rhizosolenia*,

TABLE II

Monthly percentage frequency in the occurrence of Liza macrolepis *with stomachs A-Type and B-Type (Lagoon Environment)*

Month	Fish with stomachs A Type		Fish with stomachs B Type		Total fish examined
1958					
June ..	57·59	(15)	42·31	(11)	26
July ..	86·05	(37)	13·95	(6)	43
August ..	7·14	(1)	92·86	(13)	14
September ..	28·21	(11)	71·79	(28)	39
October ..	79·17	(19)	20·83	(5)	24
November ..	60·00	(9)	40·00	(6)	15
December ..	*		*		*
1959					
January ..	*		*		*
February ..	55·00	(22)	45·00	(18)	40
March ..	39·47	(15)	60·53	(23)	38
April ..	57·14	(24)	42·86	(18)	42
May ..	62·16	(23)	37·84	(14)	37
June ..	73·91	(17)	26·09	(6)	23
July ..	36·17	(17)	63·83	(30)	47
August ..	*		*		*
September ..	*		*		*
October ..	100·00	(37)	†		37
November	88·89	(16)	11·11	(2)	18
December ..	100·00	(56)	†		56
1960					
January ..	61·70	(29)	38·30	(18)	47
February ..	70·59	(24)	29·41	(10)	34
March ..	60·78	(31)	39·22	(20)	51
Over the whole period ..	63·87	(403)	36·13	(228)	631

The figures in brackets denote the number of the fish with the particular type of stomach in the total fish examined.

* Fish sample not available.

† Absent.

TABLE III

Index of preponderance of food items of L. macrolepis *from Lagoon Environment*

Type of stomach and food items	Percentage of occurrence (O_i)	Percentage of volume (V_i)	V_iO_i	$\frac{V_iO_i}{\Sigma V_iO_i} \times 100$
Type A stomach				
Decayed organic matter	23·11	22·08	510·27	23·15 (2)
Foraminifera ..	22·01	22·82	502·27	22·78 (3)
Algae ..	13·35	4·98	66·48	3·01 (5)
Diatoms ..	17·55	4·59	80·55	3·65 (4)
Copepods ..	0·87	0·30	0·26	0·01 (6)
Sand and spicules ..	23·11	45·23	1045·26	47·40 (1)
Total Σ ..	100·00	100·00	2205·09	100·00
Type B stomach				
Gill raker processes ..	46·18	80·09	3698·56	87·63 (1)
Copepods ..	7·84	2·43	19·05	0·45 (3)
Foraminifera ..	4·24	1·75	7·42	0·18 (4)
Diatoms ..	4·88	0·64	3·12	0·07 (5)
Decayed organic matter	2·76	0·71	1·96	0·05 (6)
Sand and spicules ..	34·10	14·38	490·36	11·62 (2)
Total Σ ..	100·00	100·00	4220·47	100·00

Chaetoceros, Thallassiothrix, Thallasionema, Triceratium, Biddulphia, Hemiaulus, Hemidiscus and *Coscinodiscus* were the other genera encountered in the analyses. Tampi (1959) has drawn attention to the occurrence of a variety of littoral diatoms that go into the formation of the 'Biological complex'. The fish would have, therefore, consumed the diatoms while feeding at the bottom.

The copepods consisted of *Metis jousseaume, Microsetella rosea, Harpacticus* spp., *Schmackeria serricaudatus, Oithona* spp., and *Macrosetella gracilis*, of which the first three were the most common. The fact that they form a small fraction of the stomach contents and occur without any regularity in the months of the two years studied (Table IV), indicates that they are swallowed along with the food material accidentally.

TABLE IV

Monthly percentage composition of copepods in the food of mullets in the Lagoon Environment

Month	*L. macrolepis*		*M. cephalus*	
	Type A stomachs	Type B stomachs	Type A stomachs	Type B stomachs
1958				
April ..	*	*	†	*
May ..	*	*	†	3·87
June ..	†	3·21	†	5·11
July ..	0·09	4·37	†	1·13
August ..	†	4·22	†	†
September ..	0·45	†	†	†
October ..	†	†	†	*
November ..	†	2·65	†	0·71
December ..	*	*	*	*
1959				
January ..	*	*	*	*
February ..	†	†	†	1·18
March ..	†	1·20	0·34	2·28
April ..	†	2·40	†	2·86
May ..	†	2·62	†	2·50
June ..	†	4·99	†	5·00
July ..	†	3·95	†	4·38
August ..	*	*	*	*
September ..	*	*	*	*
October ..	1·18	*	0·88	*
November ..	0·42	†	0·56	*
December ..	0·57	*	0·40	*
1960				
January ..	0·38	3·93	0·95	5·77
February ..	†	†	†	6·70
March ..	†	3·95	†	4·21
Over the whole period ..	0·30	2·43	0·21	2·12

* Fish sample not available. † Absent.

The sand grains which occurred in the stomach contents together with minute quantity of sponge spicules throughout the study point out clearly to the browsing habit of the fish on the bottom deposits. It is possible that at least part of the spicules found in the stomachs is through ingesting foraminifera since species of the latter build houses with sponge spicules (Hardy, 1959, p. 121).

Altogether 63·28% of the fish examined during this study have been actively feeding. The monthly percentage of occurrence of the actively feeding fish is shown in Fig. 1. During 1959, a higher percentage of actively feeding fish was noted during October to December when about 73 to 89%

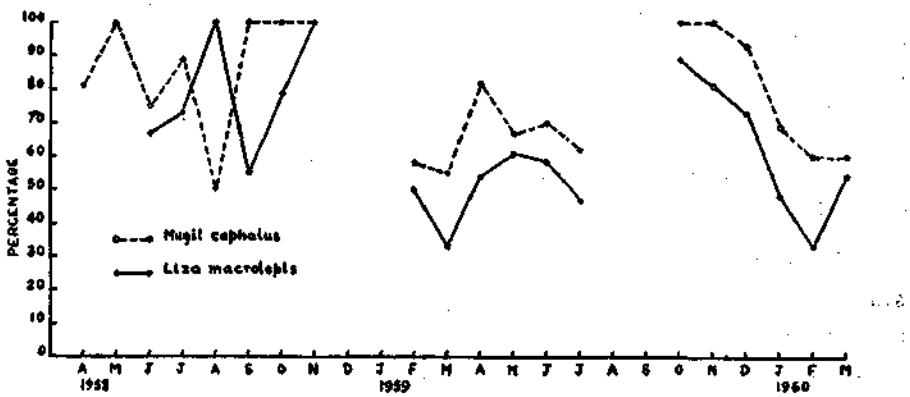

FIG. 1. Monthly percentage of occurrence of the actively feeding fish with Type A stomachs (Lagoon Environment).

of the fish examined were in this state of feeding. In 1958, besides October and November, such an increase in the feeding activity was also seen during June and July. This active feeding during June and July is considered to be due to the greater availability of fine decayed organic matter which had been drained into the lagoon from the surrounding areas consequent on an unusual rainfall during April and May, 1958 (Table X). It may also be stated in this connection that there was fishing in the lagoon during August and September 1958 on account of the unusual rainfall. Otherwise, drought conditions prevail in the lagoon during the months of August and September as in 1959, when fishing was discontinued. The small number of fish sampled during the two months (June and July) of the two consecutive years does not warrant a statistical test of significance. However, a test of significance is made for *M. cephalus* for which observations were made on a larger sample and over a wider period, *viz.*, from April to July. The very small number of fish examined does not warrant inclusion of August 1958 in the active

feeding months. Fish with stomachs in reduced feeding condition formed 23·82%. Although the percentage of such stomachs exceeded their average in majority of the months of their occurrence, a marked increase which varied from 25·81 to 45·46% with an average at 39·5% was seen during January to March.

During the monsoon as well as during the heavy rains in other periods of the year, the decayed organic matter in the stomachs was fine-grained, while during the rest of the year the same was found to be coarse. Though there was no remarkable seasonal variation in the volumetric composition of the decayed organic matter consumed, it was slightly lesser during the rainy months than during the other months. It formed a fairly large percentage in the food consumed during summer months. When the percentage of decayed organic matter was high, foraminifera consumed were relatively low and *vice versa.*

A definite seasonal succession of the different genera of foraminifera could not be made out.

Algae formed part of food in small quantities throughout the period studied. They were present to the extent of 0·49 to 13·75% of the total stomach contents. May-June and October were the peak periods of their abundance in the diet forming 11·54 to 13·75%. The October peak was characterised by the presence of *Trichodesmium, Lyngbya, Microcoleus* and *Spirulina,* while the May-June peak was characterised by *Chroococcus, Aphanothece* and several algal spores. In the month of February they were either scarce or altogether absent.

Diatoms formed part of food throughout the period of study comprising of 0·94 to 11·38% of the stomach contents in the different months. A peak period in their abundance in the diet was seen during October-November, forming 4·82 to 11·38% of the total stomach contents. They were scarce in the food taken during March. While *Pleurosigma* dominated the two other common diatoms, *viz., Navicula* and *Nitzschia* ingested during most part of the year, *Navicula* and *Nitzschia* also came into prominence during October-December.

Copepods occurred in the stomach contents conspicuously during the period October 1959 to January 1960, and during July and September 1958. Occurrence of swarms of harpacticoid copepods had been observed by Tampi (1959) in the lagoon plankton at intervals during the months following the floods and becoming scarce in the summer period.

Summing up the general biological characteristics of the Pullamadam lagoon, Tampi (1959) has stated that there are two phytoplanktonic maxima in the year, the first starting at the close of May and lasting until end of July and a second one from the end of October to November. Considering together the seasonal abundance of the diatoms and algae in the stomach contents, a close relationship is indicated between the availability of the food item in the environment and consumption of the same by the mullet.

(*b*) L. macrolepis *from Lagoon Environment—Type B Stomachs*

These stomachs constituted 36·13% of the total fish examined (Table II). A perusal of the 'Index of Preponderance' (Table III) makes it evident that the gill raker processes item, which formed 87·63%, is the only important one in these stomachs. Sand grains with spicules formed 11·62%. The remaining food items, *viz.*, Copepods, foraminifera, diatoms and decayed organic matter were rather insignificant; algal matter was rare or negligible when present in the stomach contents.

The gill raker processes present in the stomachs were in the form of single strips as those from individual gill rakers and also in the form of composite structures from all the gill rakers of an entire arch retaining their natural connections. Some were also in varied stages of fragmentation of the individual and composite strips. The foramimifera met with belonged to the same genera noted in the earlier type of stomachs. The diatmos were represented generally by *Pleurosigma, Nitzschia* and *Navicula.*

Among the copepods *Harpacticus* spp. dominated, closely followed by *Microsetella rosea* and *Metis jousseaume.* They were mostly seen entangled in the much crumpled composite strips of the gill raker processes. These copepods are known to be benthic and omnivorous occurring along with seaweeds and other organisms. A glance at Table IV will reveal a striking difference in the relative paucity of the copepods in Type A stomachs. The foregoing observations suggest that the composite structures of the gill raker processes harbour the harpacticoid copepods. A natural inference from the above statement is that the gill raker processes were present freely in the lagoon environment for some time at least before they were ingested. The percentage composition and occurrence of sand grains with spicules together with the other items, *viz.*, foraminifera and diatoms common at the bottom, lend support to the view that the gill raker processes had been ingested from the bottom surface of the lagoon.

Table II also gives the seasonal fluctuations in the occurrence of stomachs with gill raker processes. Fish with these stomachs were seen throughout

TABLE V

Index of preponderance of food items of L. macrolepis *in different stages of sexual maturity (Marine Environment)*

State of sexual maturity and food items	Percentage of occurrence (O_i)	Percentage of volume (V_i)	V_iO_i	$\frac{V_iO_i}{\Sigma V_iO_i} \times 100$
Immature (29)				
Decayed organic matter	25·78	35·19	907·20	41·04 (2)
Foraminifera ..	10·32	6·08	62·75	2·84 (4)
Algae ..	17·52	4·71	82·52	3·72 (3)
Diatoms ..	16·49	2·84	46·83	2·12 (5)
Copepods ..	1·03	0·39	0·40	0·02 (7)
Gill raker processes ..	4·12	7·06	29·09	1·32 (6)
Sand and spicules ..	24·74	43·73	1081·88	48·94 (1)
Total Σ ..	100·00	100·00	2210·67	100·00
Maturing (30)				
Decayed organic matter	25·00	34·04	851·00	39·41 (1)
Foraminifera ..	8·33	5·00	41·65	1·93 (5)
Algae ..	3·33	0·74	2·46	0·11 (6)
Diatoms ..	20·00	4·34	86·80	4·02 (4)
Copepods ..	23·34	17·94	418·72	19·39 (3)
Gill raker processes ..	..	..	..	..
Sand and spicules ..	20·00	37·94	758·80	35·14 (2)
Total Σ ..	100·00	100·00	2159·43	100·00
Spent (34)				
Decayed organic matter	24·63	30·83	759·34	36·11 (2)
Foraminifera ..	9·70	5·30	51·41	2·44 (5)
Algae ..	3·73	0·95	3·54	0·17 (6)
Diatoms ..	20·15	3·21	64·68	3·08 (4)
Copepods ..	20·15	15·30	308·29	14·66 (3)
Gill raker processes ..	0·75	0·60	0·45	0·02 (7)
Sand and spicules ..	20·89	43·81	915·19	43·52 (1)
Total Σ ..	100·00	100·00	2102·90	100·00
Spent recovering (7)				
Decayed organic matter	24·14	39·09	943·63	42·49 (1)
Foraminifera ..	10·34	10·00	103·40	4·66 (5)
Algae ..	20·69	10·00	206·90	9·32 (3)
Diatoms ..	20·69	6·06	125·38	5·65 (4)
Copepods ..	..	..	..	..
Sand and spicules ..	24·14	34·85	841·28	37·88 (2)
Total Σ ..	100·00	100·00	2220·59	100·00

* The figures in brackets are the number of fish examined.

except during October and December 1959. Their occurrence during July 1958 and November 1959 was comparatively less.

The general condition of feeding in these stomachs was low, the half full, quarter full and 'trace' stomachs having formed 23·69%, 32·89% and 32·89% respectively in the total of the Type B stomachs examined over the whole period. Stomachs three-fourth full and full were scarce being 5·26% and 0·88% respectively while gorged stomachs were absent. Actively feeding fish formed only 6·14% and still higher percentages of occurrence were noticed in the months of August and November of 1958 and in February and March of 1959. Fish in low feeding activity formed 70·17% and still higher percentages of occurrence were noticed in 1958 in the months of July, September and October; in 1959 in April and November, and in 1960 from January to March.

(*c*) L. macrolepis *from Marine Environment*

The component items in the diet of the fish from Palk Bay remained the same as in those from the lagoon. Decayed organic matter was nearly similar to the one met with in the lagoon during summer months. Algae belonging to the genera *Aphanothece, Chroococcus, Spirulina, Lyngbya, Microcoleus, Trichodesmium* and some other green algae, and diatoms of the genera *Pleurosigma, Navicula, Nitzchia, Coscinodiscus, Biddulphia, Rhizosolenia, Thallassiothrix, Triceratium* and *Chaetoceros* were observed in the stomach contents. The copepod item consisted of the genera *Microsetella* and its nauplii, *Oithona* and *Corycaeus* and rarely *Harpacticus.*

Although the diet of the fish remained almost the same as in the lagoon, there were considerable differences in the percentage of volume and occurrence of the different items. The decayed organic matter formed the predominant food item. Foraminifera was much less. Copepod item indicated an increase. A preliminary examination of the data also revealed differences in the food taken between the immature and the spent recovering fish on the one hand and the maturing and spent fish on the other. The 'Index of Preponderance' of each item of food, in the different stages of maturity mentioned are presented in Table V. A careful examination of these tables reveals that in the immature and spent recovering fish the decayed organic matter was the chief item consumed. Next in importance were algae, diatoms, foraminifera and gill raker processes. The copepod item was negligible.

In the maturing fish, the decayed organic matter and foraminifera presented a similar picture as in the immature ones. A distinct difference,

TABLE VI

Index of preponderance of food items in the fry and fingerlings of L. macrolepis *in the different size-groups*

Size-group* and food items	Percentage of occurrence (O_i)	Percentage of volume (V_i)	V_iO_i	$\frac{V_iO_i}{\Sigma V_iO_i} \times 100$
14–16 mm. (36)				
Decayed organic matter	8·69	1·07	9·30	0·13 (3)
Algae ..	2·18	0·05	0·11	0·00 (5)
Diatoms ..	4·35	0·47	2·04	0·03 (4)
Copepods ..	76·09	94·77	7211·05	99·40 (1)
Miscellaneous matter ..	8·69	3·64	31·63	0·44 (2)
Total Σ ..	100·00	100·00	7254·13	100·00
17–24 mm. (97)				
Decayed organic matter	28·23	21·55	608·36	23·33 (2)
Algae ..	16·94	6·41	108·59	4·16 (3)
Diatoms ..	17·74	3·48	61·74	2·37 (4)
Copepods ..	29·43	61·18	1800·53	69·05 (1)
Miscellaneous matter ..	5·24	3·66	19·18	0·74 (5)
Sand and spicules ..	2·42	3·72	9·00	0·35 (6)
Total Σ ..	100·00	100·00	2607·40	100·00
25–32 mm. (29)				
Decayed organic matter	37·67	55·14	2077·12	77·92 (1)
Algae ..	7·79	15·35	119·58	4·49 (4)
Diatoms ..	20·78	8·05	167·28	6·28 (3)
Copepods ..	5·19	5·56	28·86	1·08 (6)
Miscellaneous matter ..	7·79	4·44	34·59	1·30 (5)
Sand and spicules ..	20·78	11·46	238·14	8·93 (2)
Total Σ ..	100·00	100·00	2665·57	100·00
33–40 mm. (9)				
Decayed organic matter	37·50	63·00	2362·50	78·11 (1)
Algae ..	20·82	21·00	437·22	14·45 (2)
Diatoms ..	16·67	6·00	100·02	3·31 (4)
Copepods ..	4·17	1·67	6·96	0·23 (5)
Miscellaneous matter ..	4·17	1·67	6·96	0·23 (5)
Sand and spicules ..	16·67	6·66	111·02	3·67 (3)
Total Σ ..	100·00	100·00	3024·68	100·00
41–48 mm. (12) ..				
Decayed organic matter	27·90	12·79	356·84	14·82 (3)
Algae ..	23·26	55·90	1300·23	54·01 (1)
Diatoms ..	23·26	21·80	507·07	21·06 (2)
Copepods ..	..	..	..	..
Miscellaneous matter ..	..	..	..	..
Sand and spicules ..	25·58	9·51	243·27	10·11 (4)
Total Σ ..	100·00	100·00	2407·41	100·00

* The figures in brackets are the number of fish examined.

however, could be seen in the algae and copepods consumed. The index of algae was low and of copepods considerably high when compared to the immature fish. The food of the spent fish presented a close similarity to that of the maturing fish.

A gradual increase in the feeding activity was seen from immature to maturing, spent and spent recovering. About 31% immature fish, 40% maturing, 50% spent and 57% spent recovering were found to be actively feeding. In the fish from the sea, the condition of feeding was comparatively less than those from the lagoon.

(*d*) L. macrolepis—*Fry and Fingerlings*

The 'Index of Preponderance' of the various food items is given in Table VI. It is seen that fry up to 16 mm. total length fed almost at the surface chiefly on the planktonic copepods, the commonest of which were *Corycaeus* spp. Other forms met with were *Microsetella rosea*, *Oithona* spp. and *Metis jousseaume*. Decayed organic matter, diatoms, algae and miscellaneous matter (Polychaete larvae and Cypris larvae) formed only a minor fraction of the stomach contents.

From 17 mm. total length onwards, there seems to be a gradual change over from the surface feeding habit to the bottom feeding habit. Copepods still formed the chief constituent of food in the group from 17 to 24 mm., but the dominance maintained hitherto by *Corycaeus* spp. ceased to exist. A number of copepod genera, planktonic as well as benthic, *viz.*, *Corycaeus*, *Microsetella*, *Oithona*, *Euterpina*, *Metis* and *Harpacticus* in varying proportions were noticed in the individual stomachs. Sand grains, decayed organic matter, algae and diatoms appeared in appreciable proportions together with bottom dwelling copepods dominated by *Harpacticus* spp. in fish of about 25 mm. in total length, at which the adult feeding habit may be considered to have commenced.

The main feature of the next size group from 25 to 32 mm. is that the index of decayed organic matter consumed has increased considerably. There is also a marked decrease in the 'Index of Preponderance' of copepods (Harpacticoid) and miscellaneous matter in the diet. The same trend is continued in the next group from 33 to 40 mm.

In fish from 41 to 48 mm. in total length, a considerable increase in the indices of algal filaments, sand grains and diatoms accompanied by the absence of copepods and miscellaneous matter was observed indicating a marked change over to the active browsing habit of the full-grown mullet.

TABLE VII

Monthly percentage frequency in the occurrence of Mugil cephalus *with stomachs A Type and B Type (Lagoon Environment)*

Month	Fish with stomachs A type		Fish with stomachs B type		Total fish examined
1958					
April	100·00	(16)	†	†	16
May	71·43	(20)	28·57	(8)	28
June	38·71	(12)	61·29	(19)	31
July	61·29	(19)	38·71	(12)	31
August	7·69	(2)	92·31	(24)	26
September	57·14	(20)	42·86	(15)	35
October	100·00	(9)	†	†	9
November	28·57	(4)	71·43	(10)	14
December	*	*	*	*	*
1959					
January	*	*	*	*	*
February	54·29	(19)	45·71	(16)	35
March	29·73	(11)	70·27	(26)	37
April	70·97	(22)	29·03	(9)	31
May	72·98	(27)	27·02	(10)	37
June	71·43	(10)	28·57	(4)	14
July	80·56	(29)	19·44	(7)	36
August	*	*	*	*	*
September	*	*	*	*	*
October	100·00	(17)	†	†	17
November	100·00	(30)	†	†	30
December	100·00	(15)	†	†	15
1960					
January	74·19	(23)	25·81	(8)	31
February	76·92	(10)	23·08	(3)	13
March	66·67	(20)	33·33	(10)	30
Over the whole period	64·92	(335)	35·08	(181)	516

The figures in brackets denote the number of fish with the particular type of stomach in the total fish examined.

* Fish sample not available. † Absent.

TABLE VIII

Index of preponderance of food items of M. cephalus *from Lagoon Environment*

Type of stomach and food items	Percentage of occurrence (O_i)	Percentage of volume (V_i)	V_iO_i	$\frac{V_iO_i}{\Sigma V_iO_i} \times 100$
Type A stomach				
Decayed organic matter	21·93	21·66	475·00	22·33 (2)
Foraminifera ..	20·92	22·45	469·65	22·08 (3)
Algae ..	17·00	4·23	71·91	3·38 (4)
Diatoms ..	17·28	3·92	67·74	3·19 (5)
Copepods ..	0·94	0·21	0·20	0·01 (6)
Sand and spicules ..	21·93	47·53	1042·33	49·01 (1)
Total Σ ..	100·00	100·00	2126·83	100·00
Type B stomach				
Gill raker processes ..	48·78	87·14	4250·69	92·80 (1)
Copepods ..	11·07	2·12	23·47	0·51 (3)
Foraminifera ..	4·31	0·88	3·79	0·08 (4)
Diatoms ..	3·77	0·37	1·39	0·03 (5)
Decayed organic matter	0·26	0·02	0·01	0·00 (6)
Sand and spicules ..	31·81	9·47	301·24	6·58 (2)
Total Σ ..	100·00	100·00	4580·59	100·00

2 (*a*) Mugil cephalus *from Lagoon Environment—Types A and B Stomachs*

In *Mugil cephalus* the percentage occurrence of these stomachs (Table VII), the qualitative and quantitative composition of the feed (Table VIII) and their seasonal fluctuations remained about the same as in *L. macrolepis*. Actively feeding fish with Type A stomachs formed slightly a higher percentage of 79·40% in *M. cephalus*, as compared with 63·28% in *L. macrolepis*. The monthly occurrence of actively feeding fish during the period of study was generally the same in both the species of mullets, it being pronounced (93 to 100%) during October to December (Fig. 1). In general, feeding activity was less intense during January to March when the stomachs in reduced feeding varied from 20·00 to 31·58% with an average at 25·00%, the overall average of these stomachs being 13·73%.

The data of the actively feeding fish during the period April to July for the years 1958 and 1959 have been statistically compared with the help of t test:

$$t = \frac{p_1 - p_2}{\sqrt{\frac{p_1 q_1}{n_1 - 1} + \frac{p_2 q_2}{n_2 - 1}}}$$

where p_1 and p_2 are the percentages of the actively feeding fish, q_1 and q_2 are $(1 - p_1)$ and $(1 - p_2)$ respectively, and n_1 and n_2 are the total number of fish in the sample compared.

Type A Stomachs

Month	Year 1958		Year 1959	
	No. of fish actively feeding	Total No. of fish examined	No. of fish actively feeding	Total No. of fish examined
April ..	13	16	18	22
May ..	20	20	18	27
June ..	9	12	7	10
July ..	17	19	18	29
Total ..	59	67	61	88

	Year 1958	Year 1959
Percentage of actively feeding fish from April to July	08·0597%	69·3182%

$$t = \frac{0{\cdot}880597 - 0{\cdot}693182}{\sqrt{\frac{0{\cdot}880597 \times 0{\cdot}119403}{66} + \frac{0{\cdot}693182 \times 0{\cdot}306818}{87}}}$$

$$= \frac{0{\cdot}187415}{0{\cdot}063545}$$

$$= 2{\cdot}94932 > 1{\cdot}96$$

Therefore, p_1 and p_2 are likely to be significantly different. This difference in the intensity of feeding during the same period in the two years—1958

TABLE IX

Index of preponderance of food items of M. cephalus *from Marine Environment*

Food items	Percentage of occurrence (O_i)	Percentage of volume (V_i)	V_iO_i	$\frac{V_iO_i}{\Sigma V_iO_i} \times 100$
Decayed organic matter ..	21·10	20·18	425·79	20·37 (2)
Foraminifera ..	21·10	19·09	402·79	19·27 (3)
Algae ..	14·77	1·43	21·12	1·01 (5)
Diatoms ..	19·83	4·39	87·05	4·16 (4)
Copepods ..	2·10	0·24	0·50	0·02 (6)
Sand and spicules	21·10	54·67	1153·54	55·17 (1)
Total Σ ..	100·00	100·00	2090·79	100·00

and 1959—as explained earlier is considered to be on account of an unusual rainfall during April and May 1958.

Fish with Type B stomachs in half full, quarter full and 'trace' conditions of feeding formed 30·94%, 40·33% and 19·34% respectively over the whole period while three-fourth full and full stomachs formed 8·84% and 0·55% respectively. Gorged stomachs were absent. Actively feeding fish formed 9·39% and still higher percentages of occurrence were noticed in the months of June, July and November 1958 and June 1959. Fish in low feeding activity formed 59·67% and still higher percentages of occurrence were noticed in May, June and September of 1958, February, March and July of 1959 and in January to March of 1960. The presence of harpacticoid copepods along with gill raker processes almost throughout the period of the occurrence of the latter in the stomachs except for two months (August and September, 1959—Table IV) provides additional support to the view that these copepods probably inhabit the gill raker processes when the latter upon being shed by the fish settle at the bottom surface of the lagoon.

2 (*b*) M. cephalus *from Marine Environment*

The constituents of the dietary in these fish remained about the same as in the lagoon in qualitative and quantitative composition but for the absence of the gill raker processes (Table IX). The feeding index, 74%, being actively

TABLE X

Monthly rainfall in mm. in Mandapam region for the period 1st January 1958 to 31st March 1960

Month	Year		
	1958	1959	1960
January ..	9	39	9
February ..	4	3	72
March ..	23	0	0
April ..	68	27	..
May ..	141	61	..
June ..	0	11	..
July ..	1	0	..
August ..	30	18	..
September ..	1	0	..
October ..	65	130	..
November ..	150	351	..
December ..	23	101	..

feeding, was slightly more than that of the fish from lagoon in May and July 1959 probably to compensate the relatively low quantities of decayed organic matter and foraminifera consumed.

Analyses of stomach contents of 9 specimens ranging from 23 to 29 mm. in total length showed 53·06% decayed organic matter, 42·78% copepods, 3·06% sand grains, 0·55% diatoms and 0·55% algae. Among the copepods the harpacticoids dominated. Thus a general similarity is seen between the food of fry of both the species of mullet in the sizes mentioned.

CONCLUSIONS

The data presented in the paper point out that the grey mullets, *L. macrolepis* and *M. cephalus*, from the fingerling size onwards obtain their diet consisting mainly of decayed organic matter and foraminifera supplemented by fresh and decaying plant and animal matter, from what is known as the iliotrophic layer (as cited by Sarojini, 1954) on the substratum of their habitat.

The observations recorded here are in broad agreement with the findings on *M. tade* by Pillay (1953), on *M. parsia* and *M. speigleri* by Sarojini (1954), on *M. dussumieri* and *M. caeruleomaculatus* by Kuthalingam (1956) and on *M. cephalus* by Jacot (1920), Ghazzawi (1933), Gnanamuthu (1943), Haitt (1944) and Thomson (1954).

The conclusions differ, however, from those of Chacko and Venkataraman (1945), Jacob and Krishnamurthi (1947) and Chidambaram and Kuriyan (1952), who state that full-grown mullets are chiefly plankton feeders with occasional browsing habit at the bottom. The occasional settling of the planktonic diatoms and the occurrence of copepods and other organisms at the bottom has already been explained. It is possible for a fish with browsing habits to include them in its diet.

Unlike the fingerlings and the adults, the fry of *L. macrolepis* seem to feed on the surface plankton as those of many other species like *M. parsia* (Mookerjee *et al.*, 1946; Sarojini, 1954), *M. troscheli* and *M. waigiensis* (Chidambaram and Kuriyan, 1952), *M. tade* (Pillay, 1953), *M. dussumieri* and *M. caeruleomaculatus* (Kuthalingam, 1956). A variation in the proportion of phyto to zoo-planktonic elements has, however, been noticed by some workers, which may possibly be due to a difference in the relative abundance of the same in different localities.

A low feeding activity was seen in *L. macrolepis* in sexually immature and maturing stages when compared with those in spent stage. A large number of fish in Stages IV and V of sexual maturity had stomachs mostly quarter full and 'trace' in their condition of feed. Ghazzawi (1933) observed almost every mature *M. cephalus* and *M. capito* to contain only little or no food in their stomachs. Immature *M. dussumieri* fed more than the mature ones, but this difference was not seen in *M. caeruleomaculatus* (Kuthalingam, 1956). *M. tade* in IV–V stages of sexual maturity fed normally (Pillay, 1953). With the available information it is premature to draw any general conclusions on the feeding intensity in mullets in relation to their sexual maturity.

Experimental as well as field studies of Pillay (1953) showed that mullets prefer either decaying or fresh algae and when they are not available they subsist on decayed macrovegetation. From the present studies it is seen that the fish gorged their stomachs when fine and soft decayed organic matter, fresh algae and diatoms were available in plenty in its habitat, indicating that these items form the favourite food of the mullets.

SUMMARY

The food habits of the grey mullets, *L. macrolepis* and *M. cephalus*, were studied for a period of about two years from the lagoon near Mandapam, together with a few occasional samples from the Palk Bay.

The stomachs have been arbitrarily grouped into two types, A and B, for each species and the data obtained from each type were analysed separately.

Fish with Type A stomachs formed about 65% of the total examined for each species. Majority of them were in good condition of feeding. The contents were basically the same in both the species consisting of decayed organic matter, foraminifera, algae and diatoms from the benthic zones of their habitat.

Fish with Type B stomachs formed about 35% of the total examined for each species. Most of them were in a poor condition of feeding. Their contents were the same in both the species consisting virtually of gill raker processes of mullets together with a few harpacticoid copepods and stray and small quantities of foraminifera and diatoms.

The early juveniles of *L. macrolepis* seem to feed at the surface till they attain a total length of 16 mm. and there after they gradually change over to the bottom feeding habit of the adult which comes to prominence at 25 mm. total length.

Seasonal fluctuations observed in the volume and composition of food consumed by both the species were correlated with the relative abundance of the food material in the environment. Algae and diatoms in fresh and decaying state, and fine decayed organic matter are considered to be the favourite food items of mullets.

While the food taken by the immature *M. cephalus*, and immature and spent recovering *L. macrolepis* from sea was basically the same and similar to that of Type A stomachs from the lagoon, the maturing and spent *L. macrolepis* differed by registering an increase in the 'Index of Preponderance' in the copepod item in the diet.

ACKNOWLEDGEMENTS

The author is grateful to Dr. S. Jones, Director, Central Marine Fisheries Research Institute, Mandapam Camp, for guidance and encouragement in the work. He also thanks Dr. R. Raghu Prasad and Shri K. Virabhadra

Rao for looking through the manuscript and offering valuable suggestions. The author wishes to thank Dr. R. P. Varma for identification of the algae. He also thanks Shri G. K. Shukla, Statistical Officer of the Statistical Bureau, Andamans, for help rendered in the '*t*' test analysis.

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