ON THE FOOD OF THE SARDINES, *SARDINELLA ALBELLA* (VAL.) AND *S. GIBBOSA* (BLEEK.) OF THE MANDAPAM AREA*

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INTRODUCTION

THAT heterogeneous feeding relationship (Ivlev, 1961) in a sardine may be associated with the progressive development of gill rakers during ontogeny has become evident from the studies on the food of the Pacific sardine, *Sardinops caerulea* (Scofield, 1934) and the Japanese sardine, *Sardinops melanosticta* (Tokai Regional Fisheries Research Laboratory, 1960). This aspect has been referred to by other workers also (Larraneta, 1960) but not yet studied properly. A closely related problem is selective feeding, the investigation of which requires simultaneous collections of plankton and sardine samples, as borne out by the studies of Hand and Berner (1959) on the food of the Pacific sardine and of various workers on herring-*Calanus* relationship (Cushing, 1955). But most of the investigations in this line have not fulfilled this condition. Moreover, the reported accounts of the food of sardines refer mainly to adults, while information on the food of the young sardines, especially of the smaller length groups of the 0-year-class is scanty [Rosa (Jr.) and Murphy, 1960]. Furthermore, the general procedure of workers on the food of fishes has been to pool the sample values of food without reference to the catches and regard it as valid for the population. Obviously, the estimates so obtained would be biased.

The present account of the food of *Sardinella albella* (Val.) and *S. gibbosa* (Bleek.) of the Mandapam area deals with the problems enumerated above. Special emphasis is laid on the food of sardines of the length range 20–79 mm. (part of the 0-year-class). The items of diet are studied in relation to their occurrence in the environment (plankton). The sample values of food are

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also weighted according to the catches. Savage (1931) had also weighted the sample values of the food of the herring to catches over ten-day periods. The present account also forms part of an investigation of the biology and fishery of these sardines, part of the results of which has already been published (Sekharan, 1955, 1959).

Notes based mainly on cursory examination of stomach contents have been given by John (1939), Bapat and Bal (1950), Chacko (1956), Chacko and Mathew (1956) and Bennet (1961) in regard to *S. albella* and by Devanesan (1932) and Chacko (1946, 1949 and 1956) in regard to *S. gibbosa.* The food of *S. albella* above 12 cm. in size off Madras was studied for four months by Vijayaraghavan (1953). Fairly adequate samples of *S. gibbosa* mainly of sizes above 70 mm. were examined by Ganapati and Rao (1957) for their study of the food of this species off Waltair, but they did not record any significant difference between the stomach contents of the small and large fish. The food of *S. longiceps*, mainly of one-year-olds, was studied by Hornell and Nayudu (1924), John and Menon (1942), Nair and Subrahmanyan (1955) and Dhulkhed (1962).

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Material and Methods

As has already been reported (Sekharan, 1959), in the Mandapam area the fishing season on the Palk Bay side alternates with that on the Gulf of Mannar side. Sardines are abundant only on the Palk Bay side, where the season extends from April to October. While observations were made mainly on samples from Palk Bay, material was collected from Gulf of Mannar also, whenever available, for a year-round study. The work was undertaken during the years 1953–54 and 1954–55.

I. The Food of the Species

This is divided into two parts:

(1) Study of samples and (2) raising of the sample values to get the estimates of the food of the species in the particular area.

1. *Samples*

As is well known in regard to plankton, the main sources of variation with respect to food of sardines are: (1) gear, (2) time of collection, (3) place of collection and (4) size and condition of the fish.

Only samples of shore-seine catches were used, a restriction necessitated partly by the fact that only this type of gear is operated in the centre selected for observations on the Palk Bay Coast. (There is also the possibility that gill nets select sardines with bulging stomach.) Since fishing time was irregular, only a broad division of the fish collections into day and night samples was possible. From the Palk Bay only night samples were used, because (1) during the first 3–4 months of the season, sardine fishing is done exclusively at night, and (2) during other months also, the bulk of the fishing is at night. But even during the latter part of the season, no significant difference was observed between the stomach contents of day-caught and night-caught sardines. The most important centre for sardine fishing being Thedai-Pullamadam, material for the present study as well as for other detailed biological work was collected from this centre (*i.e.*, during the Palk Bay season).

The landings at Thedai-Pullamadam were composed exclusively of the 0-year-class (Sekharan, 1959). As stated earlier, emphasis was laid on the study of the food of the fish 20–79 mm. in length, immature and commercially important. Larger fish were also collected from different centres on the Gulf of Mannar coast for a year-round picture, but the catches were irregular and the effect of maturity on food could not be investigated. The division of fish into further length strata is discussed below.

Each sample consisted of 4–12 fish. Attempts were made to do the sampling at weekly intervals, but the nature of the fishery made it impossible to keep to this schedule. Immediately after the net was hauled ashore, the required samples were collected. Each fish was slit on the abdomen and preserved in 5% formalin.

The methods of analysis of stomach contents have been reviewed in recent years by Hynes (1950), Lagler (1952), Rounsefell and Everhart (1953) and Holt (1959). In this study the enumeration method and a modification of the points method were adopted.

In the laboratory the standard length, sex and maturity were recorded. From a series of trials undertaken in 1952, it was seen that the degree of fullness of stomach could be expressed satisfactorily as full, half-full, quarter-full, etc., and points allotted as follows:

Degree of fullness		Points
Empty	..	0
Little	..	1
¼ full	..	2
½ full	..	4
¾ full	..	6
Full	..	8
Gorged	..	10

This method has also been adopted by Davies (1957), in regard to the food of the South African pilchard *Sardinops ocellata.*

The stomachs were examined individually. From the contents large organisms like amphipods, *Lucifer*, fish, etc., if any, were separated. The rest was made up to a volume of 10 c.c., stirred well and 2 samples, each of 1 c.c., withdrawn. Each sample was spread on a plankton counting chamber and the number of each organism counted under a microscope. The average number per c.c. was multiplied by 10 to get the total number of each organism in the stomach. The food items were identified mostly upto the genera. Two common copepods were identified up to the species level. For each sampling day, the results were expressed as the number per 10 stomachs.

2. *Raising the Sample Values*

As stated before, the sample values were raised according to the catches. Since it could reasonably be expected that food might vary with length, the sardines were first divided into four broad groups: (1) 20–49 mm (2) 50–79 mm (3) 80–109 mm. and (4) 110–139 mm. This division was not purely arbitrary, for the first two groups form the bulk of the landing on the Palk Bay coast and the last two, on the Gulf of Mannar Coast. The first group consists of fish that can be landed not only by shore-seines but also by torch and hand-net boats (Sekharan, 1959). Maturity commences in the third group and the length at 50% maturity also falls in this group (Sekharan, 1955). Fish in the fourth group are more than one year old (Sekharan, 1955).

For reasons stated above, the Palk Bay and Gulf of Mannar samples had to be treated separately:

A. *Palk Bay*

Estimates were made of the average fullness of stomach and the number of each item taken on each day of sampling and for each month and season per 10 fish. Only the lunar month (full moon to full moon) is taken into account here, since the catches were generally poor during the full moon periods. The various lunar months are also given in Table V.

(i) *Fullness of Stomach*

For each month.—Let

n_{jk} = the number of fish examined in the j-th length group on the k-th day.

f_{ijk} = the fullness of stomach of the i-th fish of j-th length group on the k-th day.

N_{jk} = the total number of fish of the j-th length group landed on the k-th day.

S_{jm} = the total number of fish of the j-th length group landed during the m-th month.

$C_m = \sum_j S_{jm}$ = number of fish of all length groups landed during the m-th month.

Now, the fullness of stomach per fish of a particular length group on a particular day is

$$\bar{f}_{jk} = \frac{\sum_i f_{ijk}}{n_{jk}}. \tag{1}$$

The average fullness of stomach per fish of a particular length group during a particular month is:

$$\bar{f}_{jm} = \frac{\sum_k N_{jk} \bar{f}_{jk}}{\sum_k N_{jk}}. \tag{2}$$

The average fullness of stomach of the fish of all length groups during a particular month is

$$\bar{f}_m = \frac{\sum_j S_{jm} \bar{f}_{jm}}{\sum_j S_{jm}} . \qquad (3)$$

For the fishing season.—Two estimates were made: (1) the average seasonal value per 10 fish of a particular length group ($\bar{f}_{sj}$) and (2) the average seasonal value per 10 fish of all length groups combined ($\bar{f}_s$), *i.e.*, for the entire length range landed.

The average fullness of stomach per fish of a particular length group for the season is:

$$\bar{f}_{sj} = \frac{\sum_m S_{jm} \bar{f}_{jm}}{\sum_m S_{jm}} . \qquad (4)$$

The average fullness of fish of all length groups combined for the season is

$$\bar{f}_s = \frac{\sum_j \left(\sum_m S_{jm}\right) \bar{f}_{sj}}{\sum_j \left(\sum_m S_{jm}\right)} . \qquad (5)$$

It may also be seen that:

$$\bar{f}_s = \frac{\sum_m C_m \bar{f}_m}{\sum_m C_m} . \qquad (6)$$

(ii) *Items of Diet*

The items were classified into 29 groups (summed up to 16 groups in the tables presented here). As in the case of fullness of stomach, daily, monthly and seasonal estimates were made of the average numbers of individuals of each item per 10 fish of each length group and also per 10 fish of all length groups combined. The methods used were the same as in the case of fullness of stomach.

Estimates of the number of fish landed.—Since both sardines occurred together in the catches at Thedai-Pullamadam, the weight of catch of each species had first to be determined before estimating the number landed. Statistics of daily catches (in weight, of both species combined) could be obtained with the help of the fishermen. From this, the weight of catch of each species was determined as described below:

Let

c_k = the total weight of catch of sardines on the k-th sampling day.

Y_m = the total weight of catch of the sardines during the m-th lunar month.

s_k = the weight of the sample (consisting of both species) collected on the k-th sampling day.

a_k = the weight of *S. albella* in the sample of the k-th day.

b_k = the weight of *S. gibbosa* in the sample of the k-th day.

Then, the catch (in weight) of *S. albella* (y_{ak}) on the k-th sampling day is

$$y_{ak} = \frac{a_k}{s_k} c_k. \tag{7}$$

The weight of catch of *S. albella* during the m-th month is:

$$Y_{am} = Y_m \frac{\sum_k y_{ak}}{\sum_k c_k}. \tag{8}$$

The same procedure was adopted for the other species also.

The number of fish landed was estimated, following the procedure described by the author for oil sardine (Sekharan, 1962). The estimates were made in units of 10,000 during the 1953–54 season and 100,000 during the 1954–55 season.

B. *Gulf of Mannar*

The samples came from different centres within a distance of about 30 km. on either side of Mandapam. Hence weighting could be done only with reference to the catches actually observed (on each sampling day, only one catch could be observed and the sample was collected from it).

(i) *Fullness of Stomach*

For each month.—Let

y_{jk} = the number of fish of the j-th length group examined on the k-th day.

F_{ijk} = the fullness of stomach of i-th fish of the j-th length group on the k-th day.

Y_{jk} = the total number of fish of the j-th length group in the catch observed on the k-th day (and from which the sample was drawn).

$s_{jm} = \sum_k Y_{jk}$ = the total number of fish of the j-th length group in the catches actually observed during the m-th month.

$c_m = \sum_j s_{jm}$ = the total number of fish of all length groups in the catches observed (and sampled) during the m-th month.

Then, as before, the fullness of stomach of a fish of a particular length groups on the k-th day is

$$\bar{F}_{jk} = \frac{\sum_i F_{ijk}}{y_{jk}}. \quad (9)$$

The average per fish of the length group during a month is

$$\bar{F}_{jm} = \frac{\sum_k Y_{jk}\bar{F}_{jk}}{\sum_k Y_{jk}}. \quad (10)$$

The average per fish of all length groups combined during the month is

$$\bar{F}_m = \frac{\sum_j s_{jm}\bar{F}_{jm}}{\sum_j s_{jm}}. \quad (11)$$

For the season.—The average fullness of stomach per fish of the j-th length group during the season is

$$\bar{F}_{js} = \frac{\sum_m s_{jm}\bar{F}_{jm}}{\sum_m s_{jm}}. \quad (12)$$

The average per fish of all length groups combined during the season ($\bar{F}_s$) is

$$\bar{F}_s = \frac{\sum_j \left(\sum_m s_{jm}\right)\bar{F}_{js}}{\sum_j \left(\sum_m s_{jm}\right)} \quad (13)$$

also,

$$\bar{F}_s = \frac{\sum_m c_m\bar{F}_m}{\sum_m c_m}. \quad (14)$$

It will be apparent that the monthly and seasonal estimates will be less efficient than for the Palk Bay. This has to be attributed to the nature of the material available.

(ii) *Items of Diet*

The estimates were made in the same way as in the case of the fullness of stomach.

Estimates of the number of fish landed.—As the catch in each observed net was small (usually less than 100), the number in each length group and also the total number landed could be determined in the field itself, in units of 100. Even when the catches were larger, the required number could be estimated by sampling in the field.

The various averages mentioned above were multiplied by 10, when preparing the tables and the figures.

II. Study of Plankton

Surface plankton collections were made by the author using a ½ metre organdie net (*ca.* 36 strands/cm.) for 15 minutes from a catamaran with an outboard engine, the towing speed being 2–2½ knots. For reasons stated above, plankton was collected only during the Palk Bay season, off Thedai-Pullamadam where other observations were also made. During the 1953–54 season, plankton was collected in the morning, 5–6 hours after the fish were landed. Analysis showed that the results were not very satisfactory. Hence during the next season, plankton was collected at the time of fishing itself, mostly directly above the shoal, and at other times as close to it as the fishermen would allow, while encircling it. Plankton was preserved in 5% formalin.

Lucas (1956) has commented on the inadequacy of sampling by plankton net to determine the real composition of the community from which a fish takes its food. However, in the present study, the plankton net had to be used in the absence of simpler and more convenient methods.

The plankton samples were treated as described by Sheard (1947) and Prasad *et al.* (1952). The plankton volume was found by the displacement method. Larger organisms were separated and the rest made up to 500 c.c. After stirring well two samples, each of 1 c.c., were withdrawn. Each sample was spread on a plankton counting chamber and the number of organisms counted under a microscope. The classification of the organisms corresponded to that made in regard to the stomach contents, Only the average number per 1 c.c. is given in the tables and figures. The daily values were also summed up and averaged to get monthly and seasonal values (plankton volume and the number of organisms per 1 c.c. of standardised volume of 500 c.c.).

Prasad (1954 and 1956) and Prasad and Nair (1960) have made detailed studies of plankton of the Palk Bay and Gulf of Mannar off Mandapam.

FOOD OF *Sardinella albella*

(i) 1953–54 *Season*

This was the poorer of the two seasons studied and material from the Palk Bay was available only for 3 months. The number of fish examined was 75 from the Palk Bay and 16 from the Gulf of Mannar. No fish with empty stomach was recorded. The estimated averages per 10 fish of various length groups together with plankton data for sampling days and seasons are given in Tables I and II respectively. The monthly catches (in numbers) are given in Table V. In Fig. 1 are plotted the (lunar) monthly averages of (1) the degree of fullness of stomach and the numbers of the important items of diet per 10 fish of all length groups combined, (2) the plankton volume and (3) the numbers of the important elements of plankton per c.c. of the standardised volume (500 c.c.).

Food Elements on Sampling Days (Table I)

Although the items in the stomach contents corresponded to those found in plankton, the order of abundance was not the same. Moreover some of the elements recorded in plankton (*Noctiluca* sp., fish eggs and larvae, pteropods, *Sagitta* spp., *Oikopleura* spp., medusae, polychaete larvae, etc). were not found in stomach. (Hence not included in the tables.) But the most important difference between plankton and food was in regard to the copepod:diatom ratio (in numbers), there being comparatively more copepods in stomach than in net plankton.

Monthly Averages (Fig. 1)

The descriptions in regard to food given below refer to the monthly pooled data of all length groups, unless otherwise stated.

Degree of Fullness (*Points*)

For the 20–49 mm group only one sample could be collected (on 30 May 1953) and the degree of fullness was only 38 (about half-full). For the 50–79 mm group the degree of fullness was steady in June and July (about

TABLE

Plankton (volume in c.c. and the average number of organisms per 1 *c.c. of standardised and the average number of organisims per* 10

A. PALK BAY

L.m. = Lunar month:	3: 28–5–1953 to 26–6–1953							
sp. = Species:	*S. albella*		Plankton	*S. gibbosa*		*S. albella*	Plankton	*S. gibbosa*
D. = Date:	30–5–1953		30–5–1953	30–5–1953		6–6–1953	6–6–1953	6–6–1953
L.g. = Length-group (mm)	20–49	50–79		20–49	50–79	50–79		50–79
n. = No. of fish examined	5	12		4	7	10		10
N = Catch in nos. (×10⁻⁴)	21	21		11	10	8		14
f = Fullness of stomach	38	42		45	38	27		36
V = Plankton volume			25				40	
Items								
(1) Copepod nauplii and copepodites	63	30	74	200	310	220	90	200
(2) Copepods (*Total*) ..	**900**	**1525**	**100**	**1200**	**1070**	**520**	**465**	**840**
(3) *Microsetella rosea* ..	800	942	53	1000	770	280	80	440
(4) *Euterpina acutifrons* ..	—	—	4	—	—	60	30	40
(5) *Pseudodiaptomus* spp. ..	—	83	2	—	—	—	30	—
(6) *Acartia* spp. ..	—	—	—	—	—	—	35	—
(7) Other copepods ..	100	500	41	200	300	180	290	360
(8) Decapod larvae ..	—	—	—	—	—	—	—	40
(9) Other crustacea ..	—	—	—	50	—	40	—	60
(10) Molluscan larvae ..	70	300	37	100	37	100	103	120
(11) Diatoms (*Total*) ..	**13200**	**14167**	**148036**	**19000**	**16000**	**9400**	**130000**	**10000**
(12) *Rhizosolenia* spp. ..	2000	1167	14000	2500	300	400	45000	—
(13) *Chaetoceros* spp. ..	—	—	72000	—	—	200	32000	600
(14) *Bacteriastrum* spp. ..	5000	—	19500	—	1300	—	2000	200
(15) *Pleurosigma* spp. ..	1000	1417	5500	2000	1700	2600	3000	1200
(16) *Thalassiothrix* spp. ..	—	1417	17500	2500	—	400	35000	800
(17) Other diatoms ..	5200	10166	19536	12000	12714	5800	13000	7200
(18) Dinoflagellates ..	—	200	40	100	—	60	160	—

L.m. = Lunar month									
sp. = Species ..	*S. albella*		Plankton	*S. gibbosa*		*S. albella*		Plankton	*S. gibbosa*
D. = Date	21–6–1953		21–6–1953	21–6–1953		26–6–1953		26–6–1953	26–6–1953
L.g. = Length-group (mm)	50–79	80–109		50–79	80–109	50·79	80–109		50–79
n. = No. of fish examined	10	2		2	8	10	2		6
N = Catch in nos. (×10⁻⁴)	4	1		4	8	3	0·03		0·4
f = Fullness of stomach	40	46		40	36	55	44		47
V = Plankton volume			40					12	
Items									
(1) Copepod nauplii and copepodites	220	200	100	300	40	380	500	22	300
(2) Copepods (*Total*)	**1520**	**2400**	**115**	**1800**	**1200**	**2460**	**2400**	**53**	**2400**
(3) *Microsetella rosea* ..	1020	2100	55	1400	1000	1360	400	1	400
(4) *Euterpina acutifrons* ..	120	—	6	—	—	40	100	—	100
(5) *Pseudodiaptomus* spp. ..	—	—	5	—	—	—	—	9	—
(6) *Acartia* spp. ..	—	—	10	—	—	—	—	1	—
(7) Other copepods ..	380	300	39	400	200	1060	1900	42	1900
(8) Decaapod larvae ..	20	100	10	—	40	60	300	31	—
(9) Other crustacea ..	40	—	1	—	60	160	400	—	100
(10) Molluscan larvae ..	120	10	15	100	120	60	—	41	—
(11) Diatoms (*Totol*) ..	**22600**	**14000**	**73300**	**14000**	**13060**	**16600**	**8000**	**7334**	**16500**
(12) *Rhizosolenia* spp. ..	3200	—	9700	1000	1000	200	—	3370	—
(13) *Chaetoceros* spp. ..	600	—	22500	—	—	—	—	—	—
(14) *Bacteriastrum* spp. ..	—	—	2300	—	—	—	—	700	—
(15) *Pleurosigma* spp. ..	3800	1000	1500	1000	1000	3500	2000	30	8000
(16) *Thalassiothrix* spp. ..	6400	4000	12000	4000	2400	1400	1000	230	1000
(17) Other diatoms ..	8600	9000	25300	8000	8660	11200	5000	3004	7500
(18) Dinoflagellas ..	60	—	10	200	—	180	500	22	100

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volume of 500 *c.c.) and food of* Sardinella *spp.* (*average fullness per* 10 *stomachs* (*in points*) *stomachs*) *on sampling days in* 1953–54

A. Palk Bay (*Contd.*)

L.m. =	4. 27–6–1953 to 25–7–1953			6. 24–8–1954 to 22–9–1954					
sp. =	*S. albella*	Plankton	*S. gibbosa*	*S. albella*	Plankton	*S. gibbosa*		*S. albella*	Plankton
D. =	6–7–1953	6–7–1953	6–7–1953	29–8–1953	29–8–1953	29–8–1953		16–9–1953	16–9–1953)
L.g. =	50–79		50–79	50–79		50–79	80–109	80–109	
n. =	8		8	8		8	2	8	
N. =	40		30	0·8		0·6	0·4	0·3	
f =	38		50	70		68	70	20	
V =		30			60				18
Items:									
(1)	200	9	340	1350	130	1000	1500	250	23
(2)	**2000**	**54**	**1950**	**5100**	**90**	**4200**	**6800**	**1000**	**176**
(3)	1250	4	1200	680	40	350	500	190	—
(4)	100	4	80	140	20	200	250	80	3
(5)	—	6	—	260	50	650	1300	—	8
(6)	—	1	—	2050	10	2000	3500	150	47
(7)	650	39	670	1970	15	1000	1250	580	118
(8)	—	26	80	—	8	—	100	30	34
(9)	100	—	50	—	10	—	—	—	3
(10)	250	18	500	—	100	—	—	—	65
(11)	**18000**	**57208**	**23600**	**61250**	**3786[illegible]**	**21100**	**20550**	**7450**	**3366**
(12)	—	11000	630	10000	12000	2000	2500	1880	2300
(13)	—	21800	—	25000	330000	10000	6500	1250	150
(14)	—	35	—	6250	20000	500	1650	—	50
(15)	2500	135	5250	5000	5000	4400	5000	—	30
(16)	2000	2300	3380	1250	3000	250	1000	1250	700
(17)	13500	100023	14970	13750	8600	3950	3900	3070	136
(18)	40	50	40	—	1100	20	100	40	52

B. Gulf of Mannar

L.m. =	7. 23–9–1953 to 21–10–1953				9. 20–11–1953 to 18–12–1953			11. 19–1–1954 to 16–2–1954		
sp. =	*S. gibbosa*		*S. gibbosa*		*S. albella*	*S. gibbosa*	*S. albella*		*S. gibbosa*	
D. =	29–9–1953		20–10–1953		7–12–1953	11–12–1953	6–2–1954		6–2–1954	
L.g. =	50–79	80–109	50–79	80–100	80–109	80–109	110–139	110–139	80–109	110–139
n. =	6	6	4	4	8	8	6	2	4	4
N ($\times 10^{-2}$) =	1	6	3	51	7	11	0.8	0.3	1.3	2
f =	47	45	45	40	20	35	40	30	35	20
Items:										
(1) ..	420	230	800	700	400	730	620	600	450	250
(2) ..	**1420**	**1250**	**1630**	**1500**	**960**	**1670**	**2360**	**1500**	**1500**	**1050**
(3) ..	300	250	300	250	210	260	430	200	200	150
(4) ..	320	300	50	—	210	460	400	100	400	300
(5) ..	30	50	80	150	—	—	—	—	—	—
(6) ..	120	100	500	380	—	—	—	—	—	—
(7) ..	650	550	700	720	540	950	1530	1200	900	600
(8) ..	30	30	50	80	—	—	—	—	—	—
(9) ..	—	—	—	—	—	—	—	—	—	—
(10) ..	200	500	110	150	380	350	1100	200	250	300
(11) ..	**747600**	**691250**	**24250**	**26630**	**142600**	**135250**	**182500**	**159000**	**171000**	**79000**
(12) ..	75000	60000	2000	2500	22500	23250	8300	40000	15000	6250
(13) ..	300000	300000	10500	9500	27630	31250	38300	32000	38500	16250
(14) ..	266700	250000	500	2500	7000	—	7300	10000	—	—
(15) ..	30000	37500	5000	6000	19400	—	41700	10000	47500	23500
(16) ..	26700	25000	1250	630	22600	28500	31700	30000	—	—
(17) ..	49200	18750	5000	5500	43470	52250	55200	37000	70000	33000
(18) ..	330	250	50	130	690	50	470	200	200	100

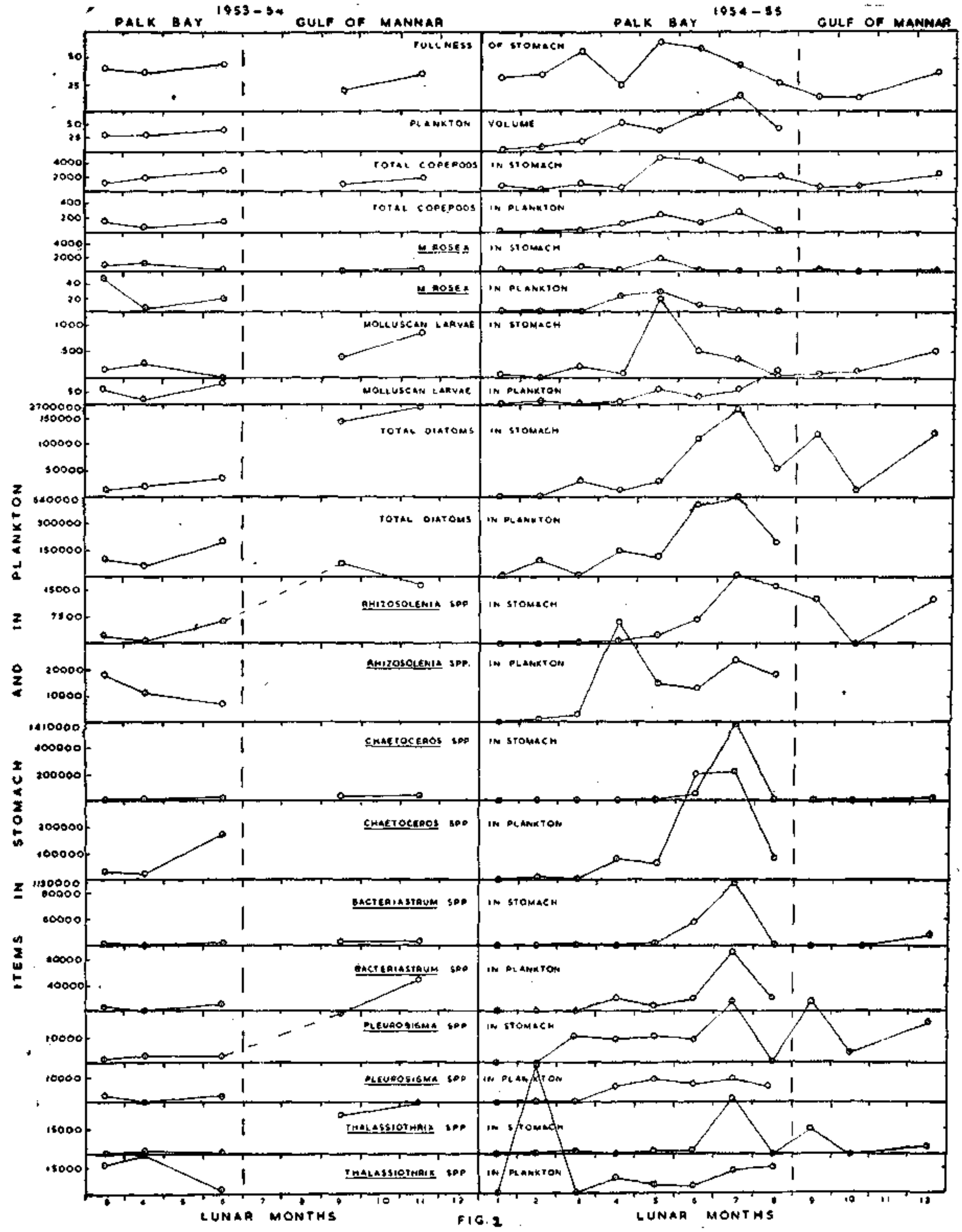

FIG. 1. Plankton (average vol. in cc and the average number of organisms per 1 c.c. of the standardised volume of 500 c.c.) and food of *S. albella* (averae fullness in points and the average number of organisms per 10 stomachs) on lunar monthly basis in 1953–55. (when fish of only one length-group was available in the collections during a month, the data for fish of that length-group are regarded as applicabie to fish of all length groups landed during the month.)

40) and increased considerably during August–September (70). On the other hand, for the 80–109 mm group, there was a decline from June (46) to September (20). For all groups combined, the fullness was steady at 38–39 points in June–July, but increased in August–September (45) and showed a positive correlation with plankton volume.

Items of Diet

Copepod nauplii and copepodites.—The trend was one of increase in stomach contents up to August–September, as in plankton.

Copepods.—The copepod content of the diet was higher in August–September than in previous months, as in net plankton. *Microsetella rosea* was the dominant species in the stomach of fish from the Palk Bay. In the food of fish from the Gulf of Mannar, both the total number of copepods and the number of *M. rosea* increased from November–December to January–February.

Molluscan larvae.—The number of molluscan larvae in stomach did not show a positive correlation with that in plankton.

Other zooplankton items.—Other zooplankton items occasionally found in stomach were crab zoea, other decapod larvae, amphipods and other crustaceans (especially *Lucifer* spp.).

Diatoms (*Total number of cells*).—The total number of cells of diatoms in the stomach of the fish rose from June to September; a similar trend was observed in net plankton also. The fluctuations in the numbers of the diatoms of important genera in the stomach contents of the fish and in the net plankton are referred to below.

Rhizosolenia spp.—For fish of the 50–79 and 80–109 mm groups from the Palk Bay, as also for all groups combined, the peak number was in August–September, unlike in the net plankton. In the stomach of fish from the Gulf of Mannar, their abundance was in November–December.

Chaetoceros spp.—The period of abundance in the stomach of fish from the Palk Bay (August–September) coincided with that in net plankton. In the stomach of fish from the Gulf of Mannar, they were abundant in January–February.

Bacteriastrum spp.—The fluctuations in the number of cells in the stomach of fish and plankton from the Palk Bay were similar. January–February was a period of high values of this diatom in the stomach contents of fish from the Gulf of Mannar.

Pleurosigma.—The number in the stomach contents of the fish from the Palk Bay was high in August–September, as in plankton, and in those from the Gulf of Mannar, in January–February.

Thalassiothrix spp.—The trends of fluctuations in the number of cells in net plankton and the stomach of the fish from the Palk Bay were similar, the peak being in June-July. In the fish from the Gulf of Mannar, the peak observed value was in January–February.

Other diatoms.—The most important of these were *Coscinodiscus* spp. It was in fact the most important genus of diatoms in the stomach contents during this year, but is not discussed separately or represented in the figure, since it was of negligible importance in the following year. The other prominent items were *Nitzschia* spp., *Biddulphia* spp., and *Thalassionema* spp.

Dinoflagellates.—The important genera were *Ceratium* spp., and *Peridinium* spp. The peak in the food of fish from the Palk Bay was in June as in net plankton, and in those from the Gulf of Mannar in November–December.

Seasonal Averages (Table II)

The data indicate that the 20–49 mm and 50–79 mm groups perhaps had better feeding opportunities than the 80–109 mm. group in the Palk Bay. The level of feeding appeared to be comparatively lower in the Gulf of Mannar than in the Palk Bay. Along with this it was found that the number of copepods was lower but the number of molluscan larvae and diatoms higher in the stomach of fish from the Gulf of Mannar than in those of fish from the Palk Bay.

The daily, monthly and seasonal averages indicate two main differences in regard to the items in stomach contents and in net plankton: (1) there were comparatively more copepods in stomach contents than in net plankton and (2) the order of abundance of the items was not always the same. These differences could have been caused by (1) the differences in the selective properties of the gill rakers and the plankton net, and (2) the time-lag between the collection of fish samples and net plankton. The second factor was sought to be eliminated during the following year, by collecting plankton at the time of fishing.

(ii) 1954–55 *Season*

Samples were available for 8 months from the Palk Bay and 3 months from the Gulf of Mannar this year. Altogether 245 fish were examined, 217

TABLE II

Plankton and food of Sardinella *spp. on seasonal basis in* 1953–54
(Details as in Table I)

A. PALK BAY

Species	*S. albella*				Plankton	*S. gibbosa*			
Length group (mm)	20–49	50–79	80–109	All groups		20–49	50–79	80–109	All groups
Catch in nos. ($\times 10^{-4}$)	171	498·5	22·9	692·4		96	367·1	72·9	
Fullness of stomach	38	39	30	37		45	43	41	
Plankton volume					32				
Items									
(1) Copepod nauplii and copepodites	63	186	246	152	64	200	307	205	
(2) *Copepods* (Total)	**900**	**1687**	**1556**	**1435**	**122**	**1200**	**1485**	**1846**	280
(3) *Microsetella rosea*	800	970	929	890	33	1000	861	974	61
(4) *Euterpina acutifrons*	—	60	44	44	10	—	48	28	80
(5) *Pseudodiaptomus* spp.	—	33	—	23	6	—	20	146	35
(6) *Acartia* spp.	—	59	101	45	14	—	62	392	97
(7) Other copepods	100	565	482	433	59	200	494	324	427
(8) Decapod larvae	—	40	62	48	16	—	41	48	35
(9) Other crustacea	—	91	8	39	2	50	37	50	42
(10) Molluscan larvae	70	215	38	168	54	100	304	100	245
(11) Diatoms (*Total*)	**13200**	**16631**	**9986**	**14951**	**115120**	**19000**	**16889**	**14295**	**17286**
(12) *Rhizosolenia* spp.	2000	902	1133	1121	13910	2500	439	1198	926
(13) *Chaetoceros* spp.	—	781	770	571	68350	—	485	728	450
(14) *Bacteriastrum* spp.	5000	180	—	1260	6369	—	348	185	240
(15) *Pleurosigma* spp.	1000	2304	406	1852	2171	2000	2912	1478	2670
(16) *Thalassiothrix* spp.	—	1777	2312	1317	13061	2500	1821	2316	2022
(17) Other diatoms	5200	10687	5365	8830	11259	12000	10884	8390	10978
(18) Dinoflagellates	—	82	28	59	64	100	33	11	43

B. GULF OF MANNAR

Species	*S. albella*			*S. gibbosa*			
Length group (mm)	80–109	110–139	All groups	50–79	80–109	110–139	All groups
Catch in nos. ($\times 10^{-2}$)	7·8	0·3	8·1	4	69·3	2	75·3
Fullness of stomach	22	30	22	48	38	20	39
Plankton volume							
Items							
(1) Copepod nauplii and copepodites	429	600	430	705	640	250	637
(2) *Copepods* (Total)	**1118**	**1500**	**1118**	**1579**	**1459**	**1050**	**1465**
(3) *Microsetella rosea*	235	200	231	300	243	150	247
(4) *Euterpina acutifrons*	233	100	225	118	103	300	109
(5) *Pseudodiaptomus* spp.	—	—	—	68	111	—	107
(6) *Acartia* spp.	—	—	—	405	280	—	281
(7) Other copepods	650	1200	662	688	722	600	721
(8) Decapod larvae	—	—	—	45	59	—	58
(9) Other crustacea	—	—	—	—	1	—	1
(10) Molluscan larvae	460	200	445	100	208	300	206
(11) Diatoms (*Total*)	**148747**	**159000**	**147200**	**205088**	**101020**	**79000**	**106524**
(12) *Rhizosolenia* spp.	21338	40000	21753	20250	10679	6250	11131
(13) *Chaetoceros* spp.	29127	32000	28856	32875	37496	16250	39550
(14) *Bacteriastrum* spp.	7129	10000	7143	67050	22785	—	24644
(15) *Pleurosigma* spp.	21991	10000	21262	11250	8299	23500	8902
(16) *Thalassiothrix* spp.	23863	30000	23781	7613	6939	—	6839
(17) Other diatoms	45299	37000	44405	16050	14822	33000	15458
(18) Dinoflagellates	1065	200	1019	538	124	100	145

from the Palk Bay and the rest from Gulf of Mannar. Among the Palk Bay fish, only 2 were from the 80–109 mm group. Seventy-eight were from the 20–49 mm group and 137 from the 50–79 mm group. Among the Gulf of Mannar samples 24 were from the 80–109 mm group and 4 from the 110–139 mm group. From the Palk Bay, the 20–49 mm group was available only for the first 4 months, while the 50–79 mm group was available for all the 8 months. The estimates of food per 10 fish and plankton data for sampling days and seasons are given in Tables III and IV respectively. The monthly catch data are presented in Table V. The monthly average estimates of food per 10 fish of all length-groups combined, along with plankton data, are plotted in Fig. 1.

Food Elements on Sampling Days

No fish with empty stomach was recorded during this season also. As before there was a close correlation between the items in plankton and food as far as their occurrence was concerned. However, their order of abundance was not always the same. This was particularly so in regard to the copepod *M. rosea*. But the most important difference noted was in the copepod: diatom ratios (in numbers). These are given below:

Sampling date		Copepod: diatom ratio in			
		Plankton	Stomach of the groups (mm)		
			20–49	50–79	80–109
April	17	1:1	1:1·6	1:3·6	
	26	1:380	1:27	..	
May	24	1:143	1:11	1:41	
	31	1:273	1:15	..	
June	9	1:115	1:115	1:485	
	23	1:2106	1:64	1:52	
	30	1:1185	1:24	1:27	
July	6	1:923	1:167	1:205	
	16	1:1048		1:5	
	30	1:19		1:1	
August	7	1:1000		1:11	
	13	1:19		1:6	
	27	1:9583		1:4·4	
September	3	1:5		1:206	
	13	1:426		1:142	
	20	1:1222		1:1395	
October	5	1:6608		1:46	
	28	1:8645		1:25	1:20

TABLE III

Plankton and food of Sardinella *spp. on sampling days in* 1954–55
(Details as in Table I)

A. PALK BAY

L.m. = Lunar month	1. 19–3–1954 to 17–4–1954					2. 1814–1954 to 16–5–1954		
sp. = Species	*S. albella*		Plankton	*S. gibbosa*		*S. albella*	Plankton	*S. gibbosa*
D. = Date	17–4–1954		17–4–1954	17–4–1954		26–4–1954	26–4–1954	26–4–1954
L.g. = Length-group (mm)	20–49	50–79		20–49	50–79	20–49		20–49
n. = No. of fish examined	8	4	—	2	4	12	—	11
N. = Catch in nos. ($\times 10^{-5}$)	0.5	0.08	—	0.1	0.7	247	—	214
f. = Fullness of stomach	34	25	—	75	40	34	—	25
V. = Plankton volume	—	—	5	—	—	—	10	—
Items:								
(1) Copepod nauplii and copepodites	138	125	5	200	250	40	15	10
(2) Copepods (*Total*)	**875**	**525**	**11**	**1900**	**1000**	**200**	**25**	**100**
(3) *Microsetella rosea*	410	250	1	300	230	60	2	45
(4) *Euterpina acutifrons*	75	—	—	900	280	—	—	—
(5) *Pseudodiaptomus* spp.	38	—	1	100	50	—	—	—
(6) *Acartia* spp.	—	—	2	—	—	—	5	—
(7) Other copepods	352	275	7	600	440	140	18	64
(8) Decapod larvae	175	125	5	—	—	—	11	—
(9) Other crustacea	—	30	—	—	80	—	—	—
(10) Molluscan larvae	75	75	12	50	10	10	13	—
(11) Diatoms (*Total*)	**1400**	**1875**	**10**	**5500**	**2750**	**5490**	**94925**	**16860**
(12) *Rhizosolenia* spp.	—	—	—	—	—	—	1000	—
(13) *Chaetoceros* spp.	—	—	—	—	—	—	14500	—
(14) *Bacteriastrum* spp.	—	—	—	—	—	—	1800	—
(15) *Pleurosigma* spp.	13	125	1	4000	2000	200	400	—
(16) *Thalassiothrix* spp.	—	—	—	—	—	830	74800	810
(17) Other diatoms	1387	1750	9	1500	750	4460	2425	16050
(18) Dinoflagellates	—	—	562	—	—	30	234	60

TABLE III (*contd.*)

A. PABLE BAY (*Contd.*)

L.m. = Lunar month .. 3. 17–5–1954 to 15–6–1954

sp. = Species ..	*S. albella*		Plankton	*S. gibbosa*		*S. albella*	Plankton	*S. gibbosa*		*S. albella*		Plankton	*S. gibbosa*
D. = Date ..	24–5–1954		24–5–1954	24–5–1954		31–5–1954	31–5–1954	31–5–1954		9–6–1954		9–6–1954	9–6–1954
L.g. = Length-group (mm)	20–49	50–79		20–49	50–79	20–49		20–49	50–79	20–49	50–79		50–79
n. = No. of fish examined ..	14	3	—	6	4	15	—	13	5	10	2	—	11
N. = Catch in nos. (×10⁻⁶)	28	10	—	25	2	3	—	10	6	16	1	—	0.6
f. = Fullness of stomach	79	58	—	63	70	33	—	27	18	28	20	—	38
V. = Plankton volume	—	—	9	—	—	—	18	—	—	—	—	20	—
Items													
(1) Copepod nauplii and copepodites ..	120	90	8	201	300	35	12	31	10	65	90	13	100
(2) Copepods (*Total*) ..	**2013**	**1200**	**32**	**1140**	**1500**	**240**	**27**	**140**	**70**	**267**	**80**	**42**	**284**
(3) *Microsetella rosea*	1350	600	—	690	600	160	2	85	50	168	60	2	200
(4) *Euterpina acutifrons*	150	90	—	—	—	10	—	10	—	60	—	4	40
(5) *Pseudodiaptomus* spp.	60	—	2	90	—	20	1	—	—	—	—	2	—
(6) *Acartia* spp. ..	—	—	5	—	—	—	2	—	—	—	—	10	—
(7) Other copepods ..	453	510	27	360	900	50	22	45	20	39	20	24	44
(8) Decapod larvae ..	—	—	9	—	—	10	14	10	10	—	—	10	44
(9) Other crustacea ..	30	30	—	—	—	10	1	—	—	—	—	—	10
(10) Molluscan larvae ..	213	600	7	90	—	90	7	70	80	69	10	—	52
(11) Diatoms (*Total*) ..	**23100**	**48990**	**4571**	**11910**	**24000**	**3660**	**7362**	**4400**	**5120**	**30710**	**38800**	**4826**	**27450**
(12) *Rhizosolenia* spp.	—	990	1300	510	3000	150	3660	180	560	255	1000	3700	980
(13) *Chaetoceros* spp. ..	210	—	1100	510	—	300	1870	1650	2100	200	—	670	330
(14) *Bacteriastrum* spp.	—	—	20	—	—	—	1080	—	—	2510	1450	80	880
(15) *Pleurosigma* spp. ..	3630	12000	710	2490	3000	2150	200	1590	1520	22650	30500	120	21770
(16) *Thalassiothrix* spp.	1710	4020	1280	990	—	—	80	—	80	350	—	—	120
(17) Other diatoms ..	17550	31980	161	7410	15000	1060	472	980	860	4750	5850	256	3478
(18) Dinoflagellates ..	129	90	177	—	—	10	24	70	40	430	100	284	355

TABLE III (*contd.*)

A. PALK BAY (*Cond.*)

L.m. = Lunar month .. 4. 16–6–1954 to 15–7–1954

sp. = Species ..	*S. albella*		Plankton	*S. gibbosa*		*S. albella*		Plankton	*S. gibbosa*		*S. albella*		Plankton	*S. gibbosa*
L.g. = Length group (mm)	23–6–1954		23–6–1954	23–6–1954		30–6–1954		30–6–1954	30–6–1954		6–7–1954		6–7–1954	6–7–1954
D. = Date	20–49	50–79		20–49	50–79	20–49	50–79		20–49	50–79	20–49	50–79		50–79
n. = No. of fish examined ..	10	4	—	4	10	7	5	—	2	12	2	11	—	12
N. = Catch in nos. ($\times 10^{-5}$)	13	1.5	—	0.3	0.2	45	34	—	0.7	28	0.007	0.1	—	5
. = Fullness of stomach	20	28	—	10	14	24	28	—	40	44	10	16	—	12
V. = Plankton volume	—	—	78	—	—	—	—	36	—	—	—	—	45	—
Items														
(1) Copepod nauplii and copepodites ..	26	10	69	10	50	77	94	68	100	12	—	10	112	10
(2) Copepods *Total* ..	**89**	**275**	**74**	**75**	**165**	**553**	**680**	**84**	**500**	**500**	**30**	**110**	**218**	**60**
(3) *Microsetella rosea*	54	185	37	68	120	157	474	19	100	140	20	70	22	30
(4) *Euterpina acutifrons*	10	30	2	—	15	73	32	25	—	67	—	10	61	10
(5) *Pseudodiaptomus* spp.	—	—	2	—	—	—	—	3	—	—	—	10	4	—
(6) *Acartia* spp. ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—
(7) Other Copepods ..	25	60	33	7	30	323	174	37	400	293	10	20	131	20
(8) Decapod larvae ..	—	—	9	—	—	—	—	9	—	10	—	—	12	—
(9) Other crustacea ..	—	10	2	—	—	—	—	—	—	—	—	—	—	20
(10) Molluscan larvae ..	12	—	12	—	—	37	224	10	—	30	—	10	15	—
(11) Diatoms *Total* ..	**5710**	**14300**	**155812**	**4510**	**6450**	**13240**	**18398**	**99525**	**17000**	**21550**	**5000**	**18460**	**201126**	**16660**
(12) *Rhizosolenia* spp.	2830	9100	32740	100	3550	—	—	69500	—	10	—	490	11520	380
(13) *Chaetoceros* spp. ..	990	—	104000	—	1500	—	—	500	—	1010	1800	7860	118656	450
(14) *Bacteriastrum* spp.	20	100	1650	—	—	—	—	250	—	—	1000	6660	61920	6790
(15) *Pleurosigma* spp.	650	1750	13000	—	50	7540	15560	1000	5000	6960	1000	1290	5184	2550
(16) *Thalassiothrix* spp.	—	—	—	—	—	—	—	26750	—	—	—	—	—	200
(17) Other diatoms ..	1220	3350	4422	3410	1350	5700	2838	1525	12000	13570	1200	2160	3846	2240
(18) Dinoflagellates ..	30	—	7	—	—	—	—	10	—	20	—	—	10	—

TABLE III (*contd.*)

A. PALK BAY (*contd.*)

L.m. 5. 16-7-1954 to 13-8-1954

sp.	*S. albella*	Plankton	*S. gibbosa*	*S. albella*	Plankton	*S. gibbosa*		*S. albella*	Plankton	*S. gibbosa*		*S. albella*	Plankton	*S. gibbosa*
D.	16-7-1954	16-7-1954	16-7-1954	30-7-1954	30-7-1954	30-7-1954		7-8-1954	7-8-1954	7-8-1954		13-8-1954	13-8-1954	13-4-1954
L.g.	50-79		50-79	50-79		50-79	80-109	50-79		50-79	80-109	50-79		50-79
n.	10	—	12	12	—	11	2	12	—	6	6	12	—	6
N.	1.6	—	6	0.6	—	1.5	0.2	0.7	—	1.5	0.5	2	—	0.1
f.	32	—	38	80	—	80	70	82	—	60	47	82	=	80
V.		46			36				60				18	
Items														
(1)	58	140	19	1267	16	791	750	650	40	683	325	1233	80	1283
(2)	861	225	570	9492	258	7380	9400	6833	215	2525	1822	6550	308	6600
(3)	736	68	507	7892	60	6680	8000	4179	10	1700	917	800	2	317
(4)	56	14	21	1042	41	390	400	1683	40	392	342	967	16	517
(5)	—	3	—	8	30	8	—	58	20	—	—	1617	39	1016
(6)	—	20	—	—	58	—	—	—	70	—	—	—	—	—
(7)	69	120	42	550	69	302	1000	913	75	433	563	3166	251	4750
(8)	—	19	—	3	37	—	—	8	37	8	3	22	37	—
(9)	—	7	—	5	7	1	—	3	3	—	20	24	9	123
(10)	23	23	81	742	118	1283	1800	1134	70	983	1050	3158	40	1033
(11)	4720	235740	7680	8492	5025	4845	6800	72925	214900	28633	16317	36475	5720	20100
(12)	180	17600	225	—	95	173	400	4667	42750	2233	967	4425	915	1900
(13)	660	175800	1000	242	65	110	600	5208	63000	1683	1417	5925	3195	2700
(14)	420	12760	125	817	70	318	1200	14833	15400	3083	1950	4350	135	1900
(15)	1060	3160	1350	842	35	245	200	30667	30800	10750	6933	14200	95	8950
(16)	40	2880	—	1183	150	882	1000	4792	18200	3583	1267	1925	935	1000
(17)	2360	23540	4980	5408	4610	3117	3400	12748	44750	7301	3783	5650	445	3650
(18)	390	1206	200	467	60	445	1400	583	510	150	200	425	20	400

TABLE III (*contd.*)

A. PALK BAY (*contd.*)

L.m.	6. 14-8-1954 to 11-9-1954								7. 12-9-1954 to 11-10-1954					
sp.	*S. albella*	Plankton	*S. gibbosa*		*S. albella*	Plankton	*S. gibbosa*		*S. albella*	Plankton	*S. gibbosa*	*S. albella*	Plankton	*S. gibbosa*
D.	27-8-1954	27-8-1954	27-8-1954		3-9-1954	3-9-1954	3-9-1954		13-9-1954	13-9-1954	13-9-1954	20-9-1954	20-9-1954	20-9-1954
L.g.	50-79		50-79	80-109	50-79		50-79	80-109	50-79		80-109	50-79		80-109
n.	12		10	2	12		15	7	12		12	10		7
N.	0.3		0.06	0.02	0.2		0.02	0.01	0.2		0.3	19		1.3
f.	82		70	70	25		56	43	53		33	44		46
V.		125				25				101			175	
Items														
(1)	1067	150	1080	1400	521	31	700	629	704	150	625	1034	336	928
(2)	7370	129	4560	5700	1083	154	1650	1583	2096	239	1323	2029	632	2814
(3)	558	20	270	300	136	1	200	159	270	—	93	233	16	514
(4)	492	30	230	500	330	15	440	321	765	69	694	170	24	357
(5)	358	10	720	800	50	11	90	71	—	—	—	90	20	43
(6)	5192	24	2350	3000	97	86	220	141	153	—	—	350	288	271
(7)	770	45	990	1100	470	41	700	891	908	170	536	1186	284	1629
(8)	13	14	10	30	10	31	125	5	5	46	—	—	16	—
(9)	10	10	50	120	23	22	6	—	2	3	1	—	—	—
(10)	775	30	990	1600	91	30	324	350	266	23	317	280	59	257
(11)	32792	936200	15730	14100	224842	814	546420	479814	298107	1017701	190588	2830080	772190	1507100
(12)	6358	26000	1890	2100	7292	70	38600	39143	7317	35400	2533	20100	28000	17580
(13)	6325	811000	4970	2300	119833	200	388200	318571	119525	752000	54967	1481500	411000	528360
(14)	3517	42000	860	1150	82750	16	93000	94429	84258	82300	39750	1187700	190500	808210
(15)	10492	14000	5310	6200	6608	6	9600	7714	8517	10000	4858	24550	9600	26340
(16)	1317	10000	200	—	3792	44	9560	11714	27568	25140	23383	33650	7200	19290
(17)	4783	33200	2500	2350	4567	478	7460	8243	50922	112861	65097	82580	125890	107320
(18)	358	2000	310	700	4	8	—	—	73	250	100	100	320	190

TABLE III (*contd.*)

A. PALK BAY (*contd.*)

L.m.	..	7. 12-9-1954 to 11-10-1954 (*contd.*)			8. 12-10-1954 to 9-11-1954				
s.p.	..	*S. albella*	Plankton	*S. gibbosa*	*S. albella*		Plankton	*S. gibbosa*	
D.	..	5-10-1954	5-10-1954	5-10-1954	28-10-1954		28-10-1954	28-10-1954	
L.g.	..	50–79		80–109	50–79	80–109		50–79	80–109
n.	..	12		9	4	2		4	2
N.	..	0.3		0.3	0.2	0.02		0.2	1
f.	..	65		60	25	40		30	30
V.	..		40				45		
Items									
(1)	..	1083	31	794	550	600	20	200	300
(2)	..	**4771**	**20**	**3489**	**2100**	**3500**	**22**	**550**	**1200**
(3)	..	767	2	1300	—	—	1	100	100
(4)	..	333	2	133	250	1300	—	—	—
(5)	..	167	1	50	—	—	2	—	—
(6)	..	400	—	33	—	—	4	—	—
(7)	..	3104	15	1973	1850	2200	15	450	1100
(8)	..	212	5	—	—	—	5	—	—
(9)	..	61	—	97	—	—	3	10	—
(10)	..	7133	87	3867	—	500	130	150	200
(11)	..	**220982**	**132168**	**62518**	**53500**	**69000**	**190200**	**29000**	**40000**
(12)	..	5508	8600	2633	15000	30000	17550	8500	15000
(13)	..	19233	68400	8522	8000	10000	80500	1000	—
(14)	..	121175	7900	24522	1500	5000	20000	—	5000
(15)	..	36933	7200	11467	—	—	5700	4000	10000
(16)	..	6192	8200	3256	—	—	15200	—	—
(17)	..	31914	31868	12178	29000	24000	51250	15500	10000
(18)	..	50	19	311	—	—	170	—	—

TABLE III (*contd.*)

B. GULF OF MANNAR

L.m.	9. 10–11–1954 to 9–12–1954				10. 10–12–1954 to 7–1–1955							12. 7–2–1955 to 7–3–1955	
sp.	*S. albella*		*S. gibbosa*		*S. albella*	*S. gibbosa*		*S. albella*		*S. gibbosa*		*S. albella*	*S. gibbosa*
D.	6–12–1954		6–12–1954		11–12–1954	11–12–1954		13–12–1954		13–12–1954		2–3–1955	2–3–1955
L.g.	80–109	110–139	80–109	110–139	80–109	80–109	110–139	80–109	110–139	80–109	110–139	80–109	110–139
n.	6	2	6	2	4	3	3	6	2	2	6	8	8
N. ($\times 10^{-2}$)	0.3	0.1	1.2	0.4	0.8	0.5	0.5	0.2	0.1	0.4	1.2	1	0.5
f.	18	10	35	20	15	60*	30*	15	10	80	33	38	30
Items													
(1)	270	200	400	200	200	1230	600	430	300	300	200	775	380
(2)	**933**	**600**	**3567**	**800**	**900**	**6900**	**3270**	**1260**	**600**	**600**	**600**	**2588**	**2260**
(3)	367	300	2167	300	150	5840	2070	—	—	200	170	425	180
(4)	133	100	400	100	150	230	230	70	100	—	200	338	650
(5)	—	—	—	—	—	—	—	170	—	—	—	—	—
(6)	—	—	100	100	—	200	30	30	100	—	—	—	—
(7)	433	200	900	300	600	630	940	990	400	400	30	1825	1430
(8)	—	—	—	—	—	—	—	—	—	—	—	—	—
(9)	—	—	—	—	—	—	—	—	—	2700	930	175	88
(10)	100	200	233	—	150	370	100	100	200	—	—	550	—
(11)	**112667**	**145000**	**124667**	**102000**	**14250**	**40190**	**38820**	**20820**	**10000**	**6500**	**14000**	**119260**	**170380**
(12)	13333	10000	7333	—	—	670	4830	—	—	—	330	13000	37900
(13)	6667	15000	15167	15000	1000	6670	330	3330	2000	—	500	24880	5500
(14)	—	—	—	—	—	—	—	—	—	—	—	15750	10880
(15)	15000	50000	20667	15000	3000	6670	10670	6330	5000	1500	2670	16250	29750
(16)	17000	10000	22167	—	—	2170	2330	330	500	—	—	4250	24000
(17)	60667	60000	59333	72000	10250	24010	20660	10830	2500	5000	10500	45130	62750
(18)	100	100	33	200	—	270	—	—	—	200	100	75	125

* Also 10 *Anchoviella* sp.   * Also 10 *Anchoviella* sp.

TABLE IV

Plankton and food of Sardinella *spp. on seasonal basis in* 1954–55
(Details as in Table I)

A. PALK BAY

Species	*S. albella*				Plankton	*S. gibbosa*			
Length group (mm)	20–49	50–79	80–109	All groups		20–49	50–79	80–109	All groups
Catch in nos. ($\times 10^{-3}$)	3064.5	609.9	0.5	3674.9	..	2125.5	454.0	62.76	2642.26
Fullness of stomach	38	43	40	39	..	35	41	31	36
Plankton volume	..	..	..	..	50	..	..	..	..
Items									
(1) Copepod nauplii and copepodites	56	444	600	120	72	45	116	501	68
(2) Copepods (*Total*)	**458**	**1809**	**3500**	**680**	**151**	**286**	**954**	**2281**	**449**
(3) *Microsetella rosea*	234	615	..	295	15	158	622	897	256
(4) *Euterpina acutifrons*	28	188	1300	55	19	2	81	190	20
(5) *Pseudodiaptomus* spp.	8	115	—	26	8	15	7	16	14
(6) *Acartia* spp.	—	190	—	32	32	1	5	72	3
(7) Other copepods	188	701	2200	272	77	110	239	1106	156
(8) Decapod larvae	0.7	5	—	1.4	18	1	7	4	1.7
(9) Other crustacea	4.1	11.1	—	5.1	4	—	5	9	1.2
(10) Molluscan larvae	40.7	502	500	119	38	1	165	644	44
(11) Diatoms (*Total*)	**10021**	**748425**	**69000**	**134504**	**226606**	**15186**	**15448**	**311387**	**22341**
(12) *Rhizosolenia* spp.	85	6165	30000	1114	16689	97	642	11218	448
(13) *Chaetoceros* spp.	66	380825	10000	64319	144803	192	1623	100810	2830
(14) *Bacteriastrum* spp.	173	305672	5000	51724	24327	—	681	153878	3779
(15) *Pleurosigma* spp.	2780	15863	—	4951	5623	531	4375	11714	1463
(16) *Thalassiothrix* sp.	818	9805	—	2324	10603	782	259	4977	795
(17) Other diatoms	6099	30095	24000	10072	24561	13584	7868	28790	13026
(18) Dinoflagellates	66	104	—	72	332	65	91	180	72
								Also 1.4 post-larval fishes	Also 0.03 post-larval fishes

B. GULF OF MANNAR

Species	*S. albella*			*S. gibbosa*		
Length group (mm)	80–109	110–139	All groups	80–109	110–139	All groups
Catch in nos. ($\times 10^{-2}$)	2.3	0.2	2.5	2.1	2.6	4.7
Fullness of stomach	26	10	25	48	30	38
Plankton volume	—	—	—	—	—	—
Items						
(1) Copepod nauplii and copepodites	488	250	424	586	270	405
(2) Copepods (*Total*)	**1693**	**600**	**1588**	**3830**	**1448**	**2476**
(3) *Microsetella rosea*	290	150	276	2688	551	1481
(4) *Euterpina acutifrons*	224	100	212	288	270	275
(5) *Pseudodiaptomus* spp.	13	—	12	—	—	—
(6) *Pseudodiaptomus* spp.	4	50	8	105	23	59
(7) *Acartia*	1162	300	1080	749	604	661
(8) Decapod larvae	—	—	—	—	—	—
(9) Other crustacea	—	—	—	—	—	—
(10) Molluscan larvae	396	200	376	644	464	582
(11) Diatoms (*Total*)	**74193**	**77500**	**73648**	**82702**	**61636**	**70243**
(12) *Rhizosolenia* spp.	7480	5000	7200	4387	8193	6447
(13) *Chaetoceros* spp.	12470	8500	12016	10339	3617	6523
(14) *Bacteriastrum* spp.	6930	—	6300	—	2067	1142
(15) *Pleurosigma* spp.	10745	27500	11968	14095	11180	12214
(16) *Thalassiothrix* spp.	4145	5250	4188	13291	5005	8581
(17) Other diatoms	32423	31250	31976	40590	31574	35336
(18) Dinoflagellates	48	50	48	173	102	132
				Also 5 post-larval fishes	Also 4 post-larval fishes	Also 4 post-larval fishes

Table V

(Lunar) monthly catch (S_{jm}, in numbers) of S. albella *and* S. gibbosa *of various length-groups (mm) at Thedai-Pullamadam in 1953–54 and 1954–55*

	Lunar months (1953–54)	1953–54 S_{jm} ($\times 10^{-4}$) *S. albella* 20–49	50–79	80–109	*S. gibbosa* 20–49	50–79	80–109
1.	March 30–April 28 ..	..	..	..	..	..	..
2.	April 29–May 27 ..	..	..	..	..	..	..
3.	May 28–June 26 ..	171	275	9	96	221	65
4.	June 27–July 25 ..	..	209	..	..	135	..
5.	July 26–August 23 ..	..	..	..	..	..	..
6.	August 24–September 22 ..	..	14.5	13.9	..	11.1	7.9
7.	September 23–October 21	..	..	..	..	..	..
8.	October 22–November 19	..	..	..	..	..	..
9.	November 20–December 19	..	..	..	..	..	..
10.	December 20–January 18	..	..	..	..	..	..
11.	January 19–February 16 ..	..	..	..	..	..	..
12.	February 17–March 18 ..	..	..	..	..	..	..

Lunar months (1954–55)	1954–55 S_{jm} ($\times 10^{-4}$) *S. albella* 20–49	50–79	80–109	*S. gibbosa* 20–49	50–79	80–109
March 19–April 17 ..	9.5	1.7	..	2.8	14	..
April 18–May 16 ..	2141	..	..	1634	..	..
May 17–June 15 ..	599	146	..	482	106	..
June 16–July 15 ..	315	195	..	6.7	194	..
July 16–August 13 ..	..	79	..	..	134	14.4
August 14–September 11	..	19.5	..	..	1.4	0·66
September 12–October 11	..	164	..	..	..	16.7
October 12–November 9	..	4.7	0·5	..	4·6	31
November 10–December 9	..	..	..	..	..	..
December 10–January 7	..	..	..	..	..	..
January 8–February 6 ..	..	..	..	..	..	..
February 7–March 7 ..	..	..	..	..	..	..

The following points emerge from this comparison:

(1) The total copepod: total diatom ratio was almost always higher in stomach than in net plankton. The notable exceptions were the ratios on June 9 and September 3, in respect of the 50–79 mm group, which can be expected on sampling considerations.

(2) The copepod: diatom ratio was almost always higher in the 20–49 mm group than in the 50–79 mm group, the only exception being that on 23rd June.

The data also indicate that the fish may have a preference for zooplankton, especially the copepod *M. rosea.* That selectivity may operate in this direction also is shown by the fact that items like *Sagitta* spp., *Oikopleura* spp., medusae, polychaete larvae, fish eggs and larvae, etc., were not found in the stomach although recorded in plankton. On the other hand, the percentage of *M. rosea* among total copepods in stomach was almost always higher than the corresponding value in plankton.

Monthly averages.—As before, the descriptions refer to the monthly data for all the length groups combined, unless otherwise stated.

Degree of Fullness

There were two periods of peak fullness for the Palk Bay fish: May–June and July–August. The 20–49 mm group was not available in the latter period and it had peak fullness in May–June. However, fullness of stomach had no positive correlation with the average volume of the standing crop of plankton. The latter had two peaks in the (lunar) months June–July and September–October, as has also been observed by Prasad (1956) who made a detailed study of plankton of the Palk Bay. During the 1954–55 season, the correlation, if any, between the monthly variations in the volume of the standing crop and stomach fullness was more negative than positive. This was true in the case of both the 20–49 and 50–79 mm groups. In fish from the Gulf of Mannar, peak fullness was in February–March; this is a peak period both for total plankton volume and the number of zooplankters (Prasad, 1956).

Items of Diet

Copepod nauplii and copepodites.—The peak in the stomach contents of fish from the Palk Bay was in September-October, the same as in plankton. Since the different stages of the various species concerned were not differentiated, they are not shown in the figure.

Copepods.—The curve for total copepods in stomach was almost parallel to that for fullness. The major peak for copepods in stomach was in July–August, when there was also a copepod peak in plankton. However, in plankton there was an additional peak for copepods in September–October, as had also been found by Prasad (1956). *Microsetella rosea* again was the dominant species in diet. It was also seen that the monthly variations in stomach fullness and in the numbers of *M. rosea* in stomach and in plankton were generally similar.

Molluscan larvae.—The two peaks for molluscan larvae in stomach coincided with peaks in stomach fullness. The first peak in plankton also coincided with the major peak in their numbers in the stomach. In the Gulf of Mannar also, the relation between fullness of stomach and molluscan larvae was positive.

Other zooplankton items.—As in 1953–54, other important zooplankton items found in stomach were crab zoea, other decapod larvae, amphipods and other crustacean forms (especially *Lucifer* spp.).

Diatoms (*Total number of cells*).—The trends of fluctuations in the total number of cells of diatoms per 10 stomach and in plankton were similar, especially during the lunar months 4–8. During the first 3 months, the sardine populations consisted mainly of the 20–49 mm group, which, as already shown, takes relatively less diatoms but more copepods, than the larger size-groups. The data also showed that unlike in the case of copepods, the peaks in stomach fullness and the number of diatoms did not fall in the same period. However, as stated by Prasad (1956) and Prasad and Nair (1960), the peaks in the abundance of various diatoms in plankton were in the same period as those for total diatoms and net plankton volume. The trends in regard to various genera in stomach and in plankton were also similar, especially during the months 4–8 (Fig. 1).

Dinoflagellates.—The peak in numbers in stomach of fish from the Palk Bay coincided with the peak in plankton. Apart from this, the correlation between plankton and food was not very evident, especially because some groups like *Noctiluca* were not found in stomach.

Seasonal Averages

The seasonal data are presented in Table IV. It will be seen that *Microsetella rosea* was the dominant copepod species in the diet, forming 51% and 34% of the copepods taken by the 20–49 and 50–79 mm groups respectively. For the entire length range from the Palk Bay its percentage was 43; in net plankton it formed on the average 10% of the total copepods. The percentages of *M. rosea* among total copepods and important genera of diatoms among total diatoms in stomach and plankton on seasonal basis are given below:

Items	Palk Bay 1953–54		Palk Bay 1954–55		Gulf of Mannar 1953–54	Gulf of Mannar 1954–55
	Stomach	Plankton	Stomach	Plankton	Stomach	Stomach
M. rosea ..	62·0	27·0	43·4	9·9	20·7	17·4
Rhizosolenia spp.	7·5	12·1	0·8	7·4	14·8	9·8
Chaetoceros spp.	3·9	59·4	47·8	63·9	19·6	16·3
Bacteriastrum spp. ..	8·4	5·5	38·5	10·7	4·9	8·6
Pleurosigma spp.	12·4	1·9	3.7	2·5	14·4	16.3
Thalassiothrix spp. ..	8.8	11·3	1·7	4·7	16·2	5·7

In 1954–55 the first, second and fourth ranks were occupied by the same organisms in stomach and in net plankton. This result offers a contrast to what was seen in the previous year, when the item of the fifth rank in stomach occupied the first rank in plankton. It may be remembered that there was a time-lag of 5–6 hours between the collection of fish samples and plankton in 1953–54. It will also be seen from the table given above that the changes, between years, in the percentages of all items except *Pleurosigma* had the same trend in food and plankton.

Remarks.—The studies reported here show that fullness of stomach is clearly related to the quantity of zooplankton in stomach, especially copepods. A close correlation between fluctuations of the items in the diet and net plankton is also seen. Some degree of selectivity in food is also indicated.

Ivlev (1961), reviewing the work of Scott (1920), Savage (1931) and Larsen (1936), thinks that the method of comparing the percentages of items in diet and in plankton is not satisfactory and proposes instead the expression

$$E = \frac{r_i - p_i}{r_i + p_i}$$

where 'E' is an index of electivity, r_i, the relative abundance of an ingredient in the ration, and p_i, the relative abundance of the same in the food complex of the environment. Adopting this for *M. rosea* the following estimates are obtained, on a seasonal basis:

$$E = 0{\cdot}39 \text{ (for 1953–54)},$$

$$E = 0{\cdot}63 \text{ (for 1954–55)}.$$

Only the percentage of this item among total copepods in stomach and plankton have been taken into account here. The results indicate a high degree of " electivity". But in regard to the other copepods, the seasonal value of ' E ' was negative. It is recognised here that a seasonal value of the electivity index is not of much significance, in view of the limitations of the methods adopted. However, the data presented in Table III show that on most of the sampling days also ' E ' for *M. rosea* was positive, the only exceptions being those found on 27th August and 28th October. These are to be expected not only because of sampling variations, but also because of various other factors mentioned by Ivlev (1961) (density of prey and predator, speed of movement of prey and predator, the degree of aggregation of the items of food, etc.).

It has however to be mentioned that this index although suitable for laboratory work may not always be satisfactory in nature, especially in filter feeders, and the index may vary widely between positive and negative values as may be seen from the data for diatoms on sampling days. Needless to say, the composition of the food complex in the environmnet is itself partly a function of the amount removed by the fishes.

The data given here also show (Table IV) that the level of feeding (fullness of stomach) was lower in Gulf of Mannar (where the fish are rare) than in the Palk Bay (where they are abundant).

FOOD OF *Sardinella gibbosa*

The study showed that the items of diet were the same as in *S. albella*; the trends of monthly fluctuations in stomach fullness, plankton volume and the different items in stomach and plankton were also generally similar. Hence a detailed account is not attempted here. Only certain points of interest, especially for the 1954–55 season are mentioned. The data for the sampling days and for the seasons are given in Tables I–IV (on the same basis as in *S. albella*). The monthly catch data are given in Table V. In Fig. 2 are plotted the monthly averages for fullness of stomach (per 10 fish of all length groups combined), plankton volume and the important items in stomach and plankton, as in Fig. 1; the details for separate genera of diatoms are omitted, as their fluctuations were generally similar to those in the case of the other sardine. No fish with completely empty stomach was observed during this study.

(i) 1953–54 *Season* (Tables I and II)

As stated earlier, the fishery was very poor during this season and only 89 fish could be examined, of which 55 were collected from the Palk Bay and 34 from Gulf of Mannar. The distribution of the Palk Bay fish was 4, 41 and 10 in the 20–49, 50–79 and 80–109 mm groups respectively; of the fish from the Gulf of Mannar, 10 were in the 50–79 mm group, 20 in the 80–109 mm group and 4 in the 110–139 mm group.

The trends of fluctuations in stomach contents and plankton were similar to those observed in the case of *S. albella*. The level of feeding (stomach fullness) was apparently lower in the Gulf of Mannar than in the Palk Bay. Among copepods, *M. rosea* was again the dominant species, forming 43% and 60% of those taken from the Palk Bay and the Gulf of Mannar respectively.

(ii) 1954–55 *Season* (Tables III and IV)

The total number of fish examined was 237, of which 207 were from the Palk Bay and the rest from Gulf of Mannar. Of the Palk Bay fish, 38 were in the 20–49 mm group, 122 in the 50–79 mm group and 47 in the 80–109 mm group. Among the fish from the Gulf of Mannar, 11 were in the 80–109 mm group and 19 in the 110–139 mm group.

Food Elements on Sampling Days

The extent of correlation between the occurrence of items in stomach contents and in plankton was similar to what was observed in *S. albella*. Some items (the same as already mentioned in the case of *S. albella*) though recorded in plankton were not found in the stomach contents. Moreover, the order of abundance of the items in stomach and plankton was not always the same. The most important difference, however, was in regard to the copepod diatom ratio (in numbers), as indicated below:

Sampling date		Copepod: diatom ratio in			
		Plankton	Length groups (in mm)		
			20–49	50–79	80–109
April	17	1:1	1:2·9	1:2·8	
	26	1:380	1:155	..	
May	24	1:143	1:10	1:16	
	31	1:273	1:31	1:73	
June	9	1:115	..	1:97	
	23	1:2106	1:60	1:39	
	30	1:1185	1:34	1:43	
July	6	1:923		1:278	
	16	1:1048		1:13	
	30	1:19		1:0·7	1:0.7
August	7	1:1000		1:11	1:9
	13	1:19		1:3	..
	27	1:9583		1:3	1:2·5
September	3	1:5		1:331	1:303
	13	1:434			1:144
	20	1:1222			1:536
October	5	1:6608		..	1:18
	28	1:8645		1:53	1:33

On 17th April, the ratios in stomach and plankton were almost equal, allowing for sampling variation. On almost all other days, the ratio was higher in stomach than in plankton, the only exception being that for 3rd September. Again, comparing the 20–49 and 50–79 mm groups, it will be seen that the ratio was almost equal for one day, higher in the former for 3 days and lesser for one day. Thus on the basis of the data for days when comparison was possible, the smaller fish, on an average, were found to take comparatively more copepods than the larger ones. Between the 50–79 and 80–109 mm groups, the ratios were almost equal.

Monthly Averages (Fig. 2)

Degree of fullness.—As before the monthly averages refer to all length groups combined. For fish from the Palk Bay there were two monthly peaks, as in the case of *S. albella.* The first peak was in the same period

(May–June) as for the other sardine. But an interesting departure was seen in regard to the second and major peak, in that it occurred one month later in this species than in *S. albella*. The explanation for this difference has perhaps to be sought, among other things, in the competition between the two species for the same diet. The earlier peak in stomach fullness was in the same period for both species, perhaps because they were small then and competition was not sufficiently pronounced. In the latter period they were larger. The samples from the Gulf of Mannar in December–January of 1954–55 contained a few post-larval fishes (*Anchoviella* sp. 21–28 mm long and *Leiognathus* spp. 15–20 mm long) which accounted for the peak in stomach fullness observed in that month.

Items of Diet

Copepod nauplii and copepodites.—As in *S. albella*, the major peak in stomach of Palk Bay fish and in plankton occurred in the same period (September–October).

Copepods.—As in *S. albella*, the total number of copepods in stomach and fullness of stomach of fish from the Palk Bay had parallel fluctuations, but the copepod peak occurred one month later in this fish than in *S. albella* and in plankton. The peak for *M. rosea*, the dominant species, was in the same period as in *S. albella* (July–August) and coincided with its peak in plankton. However, this was one month earlier than the period of peak for total copepods in stomach (from the Palk Bay). It would therefore appear that in the absence of *M. rosea*, other copepods also could make a significant contribution to the food of *S. gibbosa*.

Molluscan larvae.—The monthly fluctuations of the numbers in stomach paralleled those of stomach fullness. But the major peak for the numbers in the stomach of fish from the Palk Bay was recorded one month after the peak in plankton.

Other zooplankton items.—As in *S. albella*, the other zooplankton items found in the stomach were crab zoea, other decapod larvae, amphipods and other crustaceans (especially *Lucifer* spp.).

Diatoms (Total numbers).—The peaks for total numbers in stomach did not coincide with those for fullness of stomach (unlike in the case of copepods and molluscan larvae). But the fluctuations of the total numbers in stomach and in plankton were closely parallel. The variations in individual items also corresponded generally to those in total diatoms in stomach and plankton, as already described for *S. albella*.

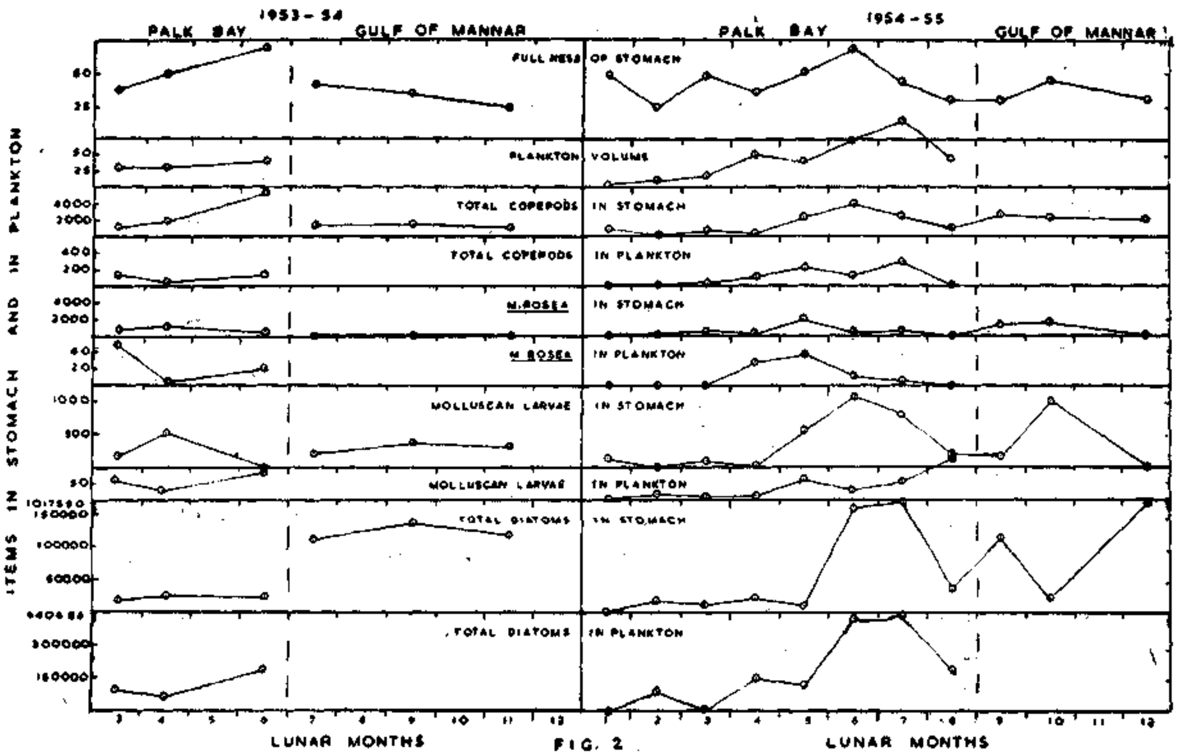

FIG. 2. Plankton and food of *S. gibbosa* in lunar monthly basis in 1953–55 (Details as in Fig. 1).

Dinoflagellates.—They were abundant in plankton in lunar months 5 and 6 (July–September). In stomach also they were abundant during these periods. *Noctiluca* was never found in stomach.

Other items.—Post-larval fishes were recorded in the stomach of the 80–139 mm groups on two sampling days, which is indicative of a developing tendency for predation on larger forms with increase in size.

Seasonal Averages (Table IV)

The level of feeding was almost the same in both the Palk Bay and the Gulf of Mannar. The percentages of *M. rosea* among total copepods and of important genera of diatoms among total diatoms (in numbers) are indicated below:

Items	Palk Bay 1953–54 Stomach	Palk Bay 1953–54 Plankton	Palk Bay 1954–55 Stomach	Palk Bay 1954–55 Plankton	Gulf of Mannar 1953–54 Stomach	Gulf of Mannar 1954–55 Stomach
M. rosea ..	60·7	27·0	57·0	9·9	16·9	59·8
Rhizosolenia spp.	5·4	12·1	2·0	7·4	10·4	9·2
Chaetoceros spp.	2·5	59·4	12·7	63·9	37·2	9·3
Bacteriastrum spp. ..	1·6	5·5	16·9	10·7	23·1	1·6
Pleurosigma spp.	15·2	1·9	6·5	2·5	8·4	17·4
Thalassiothrix spp. ..	11·9	11·3	3·6	4.7	6·4	12·2

The relation between plankton and diet, as far as diatoms were concerned, was closer in 1954–55 than in 1953–54 for reasons already mentioned.

Using Ivlev's criterion as in *S. albella*, the following values of 'E' were obtained for *M. rosea* (for all length groups on seasonal basis):

E = 0·38 (for 1953–54),

E = 0·70 (for 1954–55).

But, for other copepods (on seasonal basis) the value of 'E' was negative. Again, on almost all sampling days (Table III), the value of 'E' for *M. rosea* was positive; only on two days (30th June for 20–49 mm group and 27th August for 20–49 and 50–79 mm groups) was it negative, which again has to be expected for reasons already mentioned before. In regard to diatoms, the value of 'E' varied widely between positive and negative values.

The Gill Rakers of the Sardines

The gill rakers of the sardines were examined since the food data indicated their possible role in bringing about the disparities in the diet of the sardines of various length groups and between net plankton and the diet of the sardines. The average number of gill rakers in the sardines arranged in 10 mm size-groups are given in Table VI. It will be seen that the full complement of gill rakers characteristic of adults is attained only in sizes above 70 mm. Moreover, in the larger sardines, the gill rakers are thick and broad and lie relatively closer to one another than in the smaller ones.

TABLE VI

Average number of gill rakers in S. albella *and* S. gibbosa *of different length groups*

(Against each length group, the first figure refers to the number of fish examined and the second one, the average number of gill rakers on the first gill arch per fish of that length group. Within brackets, the average number of gill rakers on the upper limb and lower limb in that order are given.)

Length group (mm)	No. of gill rakers	
	S. albella	*S. gibbosa*
20–29	10: 45 (14+31)	10: 44 (14+30)
30–39	10: 53 (17+36)	10: 50 (16+34)
40-49	10: 62 (19+43)	10: 60 (18+42)
50–59	10: 70 (22 + 48)	10: 65 (20+45)
60–69	10: 82 (29+53)	10: 75 (25+50)
70–79	10: 84 (30+54)	10: 83 (29+54)
80–89	10: 87 (31+56)	10: 85 (30+55)
90–99	10: 90 (31+59)	10: 85 (30+55)
100–119	10: 90 (31+59)	10: 87 (30+57)
120–129	10: 95 (32+63)	10: 88 (31+57)
130–139	10: 98 (32+66)	10: 89 (31+58)

DISCUSSION

Even though the plankton samples were collected at irregular intervals during this investigation, the monthly trends of plankton fluctuations observed here generally corresponded to those recorded by Prasad (1956) and Prasad and Nair (1960), especially in regard to net plankton volume, total copepods, total diatoms and different categories of diatoms. Further the observation, made during present study, that *M. rosea* was one of the important copepods in plankton, is also in agreement with that of Prasad (1956).

On sampling days, during the present study, a good measure of agreement was seen between the occurrence of items in the stomach of the sardines and in net plankton, as was also found by Hand and Berner (1959) in their investigation of the relation of the food of the Pacific sardine (*Sardinops caerulea*) to plankton. The present results also showed that there was a close correlation between the monthly fluctuations of the important items in net plankton and the food of the sardines. In 1953–54 the increases in the numbers of total copepods, total diatoms, and most of the genera of diatoms were observed in the same period in net plankton and the stomach contents of the two sardines. During the second season, the major peaks for total diatoms and most of the important genera of diatoms in the stomach contents coincided with the major peaks of these items in plankton. Further, in 1954–55, the monthly fluctuations in the numbers of *M. rosea* in the stomach of the two sardines were similar to those in plankton. Also, in 1954–55, the major peaks for total copepods and molluscan larvae in the stomach of *S. albella* were observed in the same period as in plankton. Only in *S. gibbosa*, the major peaks for total copepods and molluscan larvae in stomach in 1954–55 were recorded one month after their peaks in net plankton. Nevertheless, considering the limitations of the methods adopted and the fact the standing crop of plankton is a dynamic balance between production and destruction in which feeding by fishes themselves has an important role, the extent of the correlation observed during the present study between the monthly fluctuations of the different items in plankton and diet of the sardines is remarkable.

The data also indicate that the correlation between the monthly fluctuations of the items in net plankton and diet of both sardines was better in 1954–55, when plankton was collected at the time of fishing than in 1953–54, when it was collected 5–6 hours after fishing. The trends of variations in plankton and stomach contents, especially of *M. rosea* and molluscan larvae, were dissimilar in 1953–54. Also, on a seasonal basis, the relative abundance of the different genera of diatoms in plankton and diet showed a better correlation in 1954–55 than in 1953–54. The results of this study therefore strongly suggest the necessity of collecting samples of fish and plankton at the same time and place when attempting a comparison between the diet of the sardines and plankton.

However the daily, monthly and seasonal data also indicated marked differences in the relative abundance of items in net plankton and the food of the sardines. The daily values especially bring out the disparities clearly. They show that, apart from other variations, the copepod diatom ratio and the percentage of *M. rosea* among copepods were higher in the stomach contents of the sardines than in net plankton. Viewing the items in stomach and in net collections on sampling days as separate samples of plankton, these differences can be expected to arise from a number of sources. Chief among them is the probable difference in the selective properties of the gill rakers and the plankton net. A proper evaluation of this difference can be made only on the basis of experiments under various environmental conditions and densities of the fishes, which could not be attempted here. However, the data presented here indicate that such differences probably exist and have to be taken into account when studying the food of filter feeders. It has been shown that the number of gill rakers increases with the length of the fish and that in the large sardines, they are thick and broad and lie relatively closer to one another than in the smaller fishes. This together with the fact that the copepod : diatom ratio is higher in the stomach of the smaller fishes than in those of the larger fishes, and in the stomach of the sardines than in net plankton indicates that gill raker selectivity may be one of the factors responsible for these variations. Groody (1952, quoted by Hand and Berner, 1959) observing the feeding of the Pacific sardine on a cloud of shrimp in aquarium, reported that the fish plunged through it with their mouths open, filtering the shrimp from the water by the gill rakers. When plankton is filtered by gill rakers, there is a greater chance for larger organisms being retained than for smaller ones (like diatoms). The same phenomenon is known in regard to plankton net collections, where nannoplankton which often forms the bulk of the standing crop, is not retained (Rodhe *et al.*, 1958; Yentsch and Ryther, 1959) and also in regard to gear selection in fishes (Sekharan, 1959). Scofield (1934) relates the dominance of copepods in the stomach of young Pacific sardine to the fact that their gill rakers are less in number and also poorly developed, compared to those of adults. No marked structural difference has been noted in the gill rakers of the Mandapam sardines of the length range examined. In the Japanese sardine, *Sardinops melanosticta*, Nakai (1938) reported that the innumerable projections on the gill rakers have serrations which bridge over adjacent gill rakers, forming triangular sievemeshes with apertures of 0·001–0·0015 mm across.

It is possible that part of the difference between net plankton and food is due to patchiness of plankton, since even simultaneous hauls with the same type of plankton net are known to give significantly different results. Evidence of aggregation or clumping of a species at a given station has been given by Ricker (1937), Langford (1938) and Barnes and Marshall (1951). However, the consistently higher copepod: diatom ratios in the stomach of sardines than in net plankton and in the stomach of the younger fishes than in those of the larger fishes found during the present study show that other factors besides patchiness may also be of great importance. There is again a possibility that the variations are due to differential digestion, the diatoms being more quickly digested than copepods. But the higher copepod: diatom ratio, in the stomachs of the younger fishes than in those of the larger ones, rules it out as a major factor, unless it is postulated that the smaller fishes digest diatoms more quickly than the larger ones.

On the other hand, the results indicate the avoidance of certain items and some degree of selective feeding on others by the sardines. Although items like medusae, *Sagitta* spp., *Oikopleura* spp., pteropods, polychaete larvae and *Noctiluca* sp. were recorded in plankton, they were not observed in the stomach contents of the sardines of the length range considered here, perhaps because they were avoided. In regard to some of these items, size may be a restricting factor. It is also possible that soft-bodied organisms like medusae are quickly digested, as suggested by Hand and Berner (1959). The fishermen commonly believe that the abundance of pteropods in plankton is detrimental to the fishery for these sardines. Prasad (1953) has shown that when *Noctiluca* is abundant in plankton the fishery for these sardines suffers a set-back. Lucas (1956) has also stated that avoidance may play an important role in the feeding habits of fishes. Muznîc (1960) has reported, on the basis of experiments, that *Sardina pilchardus* can eject unsuitable or large particles of food. If certain items can be avoided, it is probable that individual items can also be chosen. Groody (1952), quoted by Hand and Berner (1959), has shown experimentally that this happens in the Pacific sardine. Davies (1956) found that the south African pilchard (*Sardinops ocellata*) could live for as long as six months as particulate feeders in aquariums, from where all plankton had been removed.

The dominance of *M. rosea* among copepods in the stomach of both species during both the seasons therefore assumes interest in the light of the possibility that it is a preferred item. It may be remembered that it was only in regard to this species among copepods that a positive seasonal electivity index was obtained during both the years for both sardines. In 1954–55, when plankton was collected at the time of fishing, the daily electivity index also was positive for this species of copepod except on rare occasions. (The daily electivity index for this species was positive in 1953–54 also, but is not considered here because of the time-lag between the collection of samples of fishes and plankton). Furthermore the fluctuations of *M. rosea* in the stomach of the sardines and plankton were closely parallel

(Figs. 1 and 2) in 1954–55. The present observations are therefore comparable, to some extent, to those of Lucas (1936, 1956) on the herring-*Calanus* relationship; he showed that abundance of *Calanus finmarchicus* in the food of the fish was closely correlated with its abundance in plankton collected at the time of fishing. Detailed investigations, however, are necessary in future to see whether *M. rosea* is really a preferred item of the diet of the sardines.

It has been shown that in the 0-year-classes of both sardines, particularly of the 20–79 mm groups from the Palk Bay, the peak period of stomach fullness coincided with that for zooplankton, especially copepods, in stomach in 1954–55 (Plankton volume peaks, on the other hand, coincided with diatom peaks). This shows that zooplankton, especially copepods, are probably more important than diatoms in the diet of these small fishes. The same conclusion can be drawn if equivalent values of copepods and diatoms for total organic contents are considered. These values are not at present available for the forms occurring in the Mandapam area. However, Brandt (1889 and 1902, quoted by Cushing, 1955) has shown that on the basis of proteins, carbohydrates, fat, silicon and ash, 0·44-0·78 copepod = 2,880 diatoms. Reference to Tables I–IV and Figs. 1 and 2 will show that the copepod : diatom ratio (for sampling days and seasons on the Palk Bay coast) in the stomachs of the fishes of the 20–79 mm groups varied from 1: 1 to 1: 1,395 in the case of *S. albella* and from 1: 0·7 to 1: 331 in the case of *S. gibbosa*. If Brandt's values are considered applicable here also, then it follows that copepods are relatively more important than diatoms in the diet of these small sardines.

Bapat and Bal (1950) found that *S. albella* of the size range 26–51 mm off Bombay, fed mainly on copepods. The larvae, post-larvae and the smaller size-groups of *Sardinops caerulea* also feed almost exclusively on copepods (Scofield, 1934; Hand and Berner, 1959; Arthur, 1952, quoted by Ahlstrom, 1960). Similar habits have been described for the post-larvae and smaller size-groups of *Sardinops melanosticta* (Tokai Regional Fisheries Research Laboratory, 1960), and *Sardina pilchardus* (Larraneta, 1960). In the latter fish, at 6–8 cm. when gill rakers are formed, filter feeding habit starts and dinoflagellates also figure in the diet. The juveniles of *Sardinops ocellata* feed on zooplankton and phytoplankton in almost equal quantities (de Jager, 1960). On the basis of total organic contents, the share of the former should probably be higher. According to Montes (1953) and Ben-Tuvia (1960) the post-larvae and juveniles of *Sardinella aurita* of the size-range 13–65 mm feed mainly on copepods and also on diatoms.

In all cases where the study has been made it has been seen that young sardines depend mainly on copepods as diet. However, the attempt to correlate this with gill raker development has been rarely made except in the cases referred to. But in certain other cases where this aspect has not been studied, the fact that the number of gill rakers increases with length of the fish has been mentioned (Ronquillo, 1960). The dominance of zooplankton and especially copepods in the food of the young sardines thus appears to be a general phenomenon. This is also perhaps true of the younger stages of all fishes. Simpson (1956) states that larvae and post-larvae typically begin by feeding on eggs, nauplii, or later stages of copepoda, cirripedia, and cladocera, *Oikopleura* or molluscan larvae.

As has already been stated, *S. albella* and *S. gibbosa*, collected from Gulf of Mannar, were mostly above 80 mm in length. But in these size-groups also, copepods constitute the major item of diet, although larger items like post-larval fishes have sometimes been found in the stomach of *S. gibbosa*. Devanesan (1932) and Chacko (1946, 1949, 1956) have also referred to the occurrence of copepods and diatoms in the stomach of this fish. Chacko (1956) and Chacko and Mathew (1956) recorded copepods and diatoms from the stomach of *S. albella*. That crustaceans form the main food of adults has been reported by Ganapati and Rao (1957) in regard to *S. gibbosa*, and Vijayaraghavan (1953) in regard to *S. albella*. It would therefore appear that from a predominantly crustacean diet in the early stages, both species change to a diet of crustacea and phytoplankton with increase in age, and at a later stage revert to a crustacean diet.

The adults of the Indian oil sardine (*Sardinella longiceps*) are phytoplankton feeders (Nair and Subrahmanyan, 1955; Dhulkhed, 1962). Accounts of the food of the adults of the other species of *Sardinella*, *Sardina pilchardus*, and *Sardinops* spp. from various regions of the world have been given in the *Proceedings of the World Scientific Meeting on the Biology of Sardines and Related Species*, Vol. 2 (edited by Rosa, Jr. and Murphy, 1960) and summarised by Rosa and Laevastu (1960). These indicate that it is difficult to classify adult sardines as phytoplankton feeders or zooplankton feeders. The differences in the findings, especially among workers on the same fish, have to be related, to some extent, to the differences in sampling, lack of data on food in the environment, and pooling of samples without reference to the catches, as already referred to.

SUMMARY

A study was made of the food of *Sardinella albella* and *S. gibeasa* in relation to plankton in 1953–54 and 1954–55. Emphasis was laid on the food

of the fishes of the 20–79 mm groups, immature and commercially important on the Palk Bay coast. For a year-round study, larger fishes were also collected from Gulf of Mannar, where the fishery is poor. The sample values of food were raised to the catches for sampling days, lunar months and seasons. Plankton was collected from the Palk Bay, 5–6 hours after the fish samples were collected in 1953, and at the time of fishing in 1954.

On sampling days there was a good measure of agreement between the occurrence of items in the stomach of the sardines and in net plankton. A close correlation was also seen between the monthly fluctuations of the items in stomach and in plankton. The monthly fluctuations in the numbers of total diatoms and different categories of diatoms in the stomach of the sardines corresponded to those in net plankton; also the abundance of the copepod *Microsetella rosea* in the stomach showed a correlation with its abundance in net plankton in 1954–55. In regard to *S. albella* the major peaks for total copepods and molluscan larvae in stomach also corresponded to peaks in net plankton (in 1954–55). Only in regard to *S. gibbosa* one of the peaks for total copepods and molluscan larvae in stomach occurred one month after their peaks in net plankton.

The correlation of the relative abundance of the various genera of diatoms in stomach of the sardines and in plankton was better in 1954–55 than in 1953–54.

However, certain differences were also found between the relative abundance of the items in stomach and in plankton especially on sampling days. The total copepod : total diatom ratio on sampling days was higher in the stomachs of the sardines than in net plankton, and in the stomach of the fishes of the 20–49 mm groups than in those of the larger fishes. The smaller fishes have less number of gill rakers than the larger ones. The probable role of gill raker selectivity in bringing about these differences in the copepod : diatom ratios is discussed.

The sardines appear to avoid certain items like medusae, *Sagitta* spp., *Oikopleura* spp., pteropods, polychaete larvae and *Noctiluca* sp., and to feed selectively on others especially the copepod, *M. rosea*. *M. rosea* was the dominant species among copepods in stomach, and its percentages among copepods in the stomachs of the sardines for sampling days, months and seasons were higher than the corresponding percentages in plankton.

In the 0-year-classes of the two sardines, particularly of the 20–79 mm groups from the Palk Bay, the peak periods of stomach fullness coincided with those for zooplankton, especially copepods, in stomach in 1954–55.

(The peaks in plankton volume, on the other hand, coincided with diatom peaks). This indicated that zooplankton, especially copepods, are probably more important than diatoms in the diet of these small fishes.

In the diet of the larger fishes from Gulf of Mannar also, copepods appeared to be more important than diatoms.

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