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THE FOOD OF TWO SPECIES OF SARDINES—*SARDINELLA GIBBOSA* (BLEEKER) AND *SARDINELLA ALBELLA* (VALENCIENNES) IN EAST AFRICAN WATERS*

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ABSTRACT

The zooplankton components of the stomach contents of *S. gibbosa* (size range 6.2–14 cm) and *S. albella* (size range 6.2–12.9 cm) caught in the Light Fishery of Dar es Salaam was investigated over a period of twelve and thirteen months for the former and latter species respectively. Both *S. gibbosa* and *S. albella* were found to prey principally on about the same fifteen groups and species of zooplankters (mostly Crustacea), whose relative abundance in the stomach of the two species showed a positive Kendall's co-efficient of concordance. For both the species of sardine, there was also a fair degree of agreement between the relative abundance of each type of prey in the stomach and the frequency of the latter which contained that particular kind of zooplanktonic prey. There were about thirty other groups and species of zooplankters in the stomachs, but most of these were in insignificant proportion or of only occasional occurrence.

The problems of (i) relationship of size of fish to the type of food eaten and (ii) the mode of clupeid feeding, are discussed in the light of present results and a comparison is made of this work with observations on the food of sardines from other areas of the Indian Ocean.

INTRODUCTION

THOUGH catch statistics of sardine landings in East African waters are lacking, experiences of the few workers (Losse, 1968; Okera, 1971) on the biology and fishery of the local sardines have shown that the two neritic species of *Sardinella*, namely *S. gibbosa* and *S. albella* (Fig. 1) are amongst the three most important commercial clupeids, the third one being *Herklotsichthyes punctatus* (Rüppell).

It is known from the results of many other workers (Blaxter and Holliday, 1963; Nair, 1960; Li Kwan-Ming, 1960; Legare & Maclellan, 1960; Hand and Berner, 1959; Rojas de Mendiola, 1969; Muzinic, 1960; Cushing, 1964; Savage, 1937) from different parts of the seas that the sardines and other clupeoids are plankton feeders. In E. African waters apart from a very brief survey by Losse (unpublished data) on the types of planktonic groups that comprise the food of the local sardines, almost nothing else is known about this trophic level. In view of the well recognised fact that food is an important factor in determining fish yield and biomass (Silliman, 1968), it was decided to undertake the following detailed investigation on the types and nature of the zooplanktonic elements that are consumed by *S. albella* and *S. gibbosa* and the relative importance of each of these elements in the diet of these two species of sardines. Night plankton, which forms the food environment of light-caught sardines were also collected in darkness and under the influence of artificial light; the results of this part of the project will be published elsewhere.

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MATERIALS AND METHODS

The two species of sardines were studied from February 1969 to March 1970. The dates and places the fish were caught and the number of specimens of each species examined for the various months are given below:

Date	Fishing ground	Number of fish examined	
		S. gibbosa	*S. albella*
17/ 2/69	Sinda	—	25
14/ 3/69	Sinda	25	24
18/ 4/69	Sinda	25	—
21/ 4/69	Msasani Bay	25	25
20/ 5/69	Sinda	25	17
12/ 6/69	Msasani Bay	18	10
20/ 6/69	Msasani Bay	–	25
July 69	–	–	–
12/ 8/69	Sinda	25	25
20/ 8/69	Msasani Bay	–	25
16/ 9/69	,,	28	23
6/10/69	,,	31	25
4/11/69	Sinda	40	25
15/12/69	Msasani Bay	25	–
9/ 1/70	,,	23	–
9/ 2/70	,,	18	25
12/ 3/70	Sinda	28	21

Except for the nights of 18/4/69, 20/6/69 and 20/8/69 when fish samples were obtained at the fishing grounds (Fig. 2), immediately after the fishing operation, on all the remaining dates fish samples were obtained from Banda Beach (Dar es Salaam) where all the catch is landed and sold after each night of fishing. Two types of commercial fishing methods operate in Dar es Salaam waters, the Japanese dip-nets or *Boke Ami* which came into operation in 1964 and the sardine purse-seines; the first one was worked in the Zanzibar area in 1961 by Greek fishermen (Losse, 1966). Both these fishing gear make use of artificial light to attract the fish which are then surrounded in the case of the purse-seine or lifted as in the case of the dip-net. Indigenous methods of sardine fishing consist of castnets and sometimes these fish are also taken in large numbers in beach seines. However, the supply of fish from any of these two methods is not dependable.

In the laboratory, after recording the routine measurements such as standard length (S. L.), standard depth (S. D.) and the wet weight, the gut content and viscera of the fish were injected with 10% neutral formol-saline, the fish were tagged with a numbered label and the whole fish was then preserved in the same fixative until at a latter date when the abdomen was opened up.

For the purposes of the examination of the stomach contents, a cut was made across the oesophagus and at the pyloric end of the stomach and the freed portion of the gut was then cut open and the contents emptied into water contained in a petri-dish. The contents were examined qualitatively and quantitatively but no attempt was made to look for and identify the phytoplankton part of the stomach contents.

RESULTS

The composition of the stomach contents of S. gibbosa *and* S. albella

All the identified organisms from the stomach contents of the two species of sardines are listed in Table 1 and the relative percentage proportion of the main components of the stomach contents of the monthly sample batches of the two species of sardines are given in Table 2 and 3 and graphically illustrated in Fig. 3.

TABLE 1. *List of organisms recorded from the stomachs of* S. gibbosa *and* S. albella

Siphonophora	Crustacea continued.
Diphyd nectophores	Other mysids
Polychaeta	Cumacea
Crustacea	Tanaidacea
Evadne sp.	Crytoniscid larvae
Cypridina sinuosa (Müller)	*Synopia variabilis* Spandl
Euconchoecia chierchiae (Müller)	Other gammarideans
Cypridinoides minuta Poulson	*Hyperia* spp.
Cycloleberis sp.	*Simorhynchotus* sp.
Synasterope sp.	*Branchyscelus* sp.
Propentocypris sp.	*Paratyphiis* sp.
Rhincalanus cornutus Dana	*Lycaea* sp.
Candacia spp.	*Paralycaea sp.*
Eucalanus spp.	*Euphausiacea* (adults)
Acartia spp.	?Calyptopis of euphausiacea
Centropages spp.	*Lucifer* spp.
Temora spp.	*Leptochela* sp.
Other unidentified calanoidea	Caridean larvae
Corycaeus spp.	Anomuran „
Oithona spp.	Brachyuran „ & postlarvae
Oncea spp.	Stomatopod larvae
Sapphirina spp.	Phyllosoma
?Copilia sp.	*Sagitta* spp.
Euterpina sp.	Mollusca
Macrosetella sp.	*Creseis acicula* Rang
Microsetella sp.	Atlantid heteropods
Clytemenestra sp.	Postlarval bivalvia
Cirripede cypris	„ gastropoda
?Anchialus (or *Anchialina?*)	Larvacea
?Gastrosaccus	*Thalia* sp.
?Siriella (or *Hemisiriella?*)	Clupeoid larvae.

The more abundant and frequent items of food

The most abundant food element in the stomachs of both the species of sardines were the calanoid copepods. Their relative percentage proportion in the stomachs of *S. gibbosa* varied between 6.1% and 79.4% (with a mean of 35.6% for the 14 sample batches) and in the stomachs of *S. albella*, it ranged between 8.4% and 81% (with a mean of 45.6% for the 14 sample batches). Nearly all the common types of calanoids that have been encountered in the plankton were also present in the stomachs and it seems that these fish consume without much discrimination, most of the commoner calanoids.

Calanoids were also the most frequently encountered item of food in the stomachs; of the total number of stomachs examined, 85.8% and 89.3% in the case of *S. gibbosa* and *S. albella* respectively had calanoids in them.

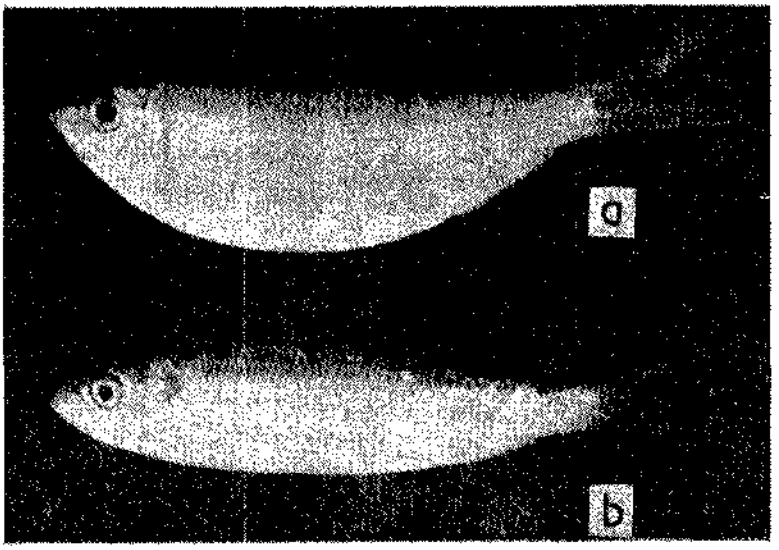

Fig. 1. a *Sardinella albella* and b. *S. gibbosa*.

Hyperiid amphipods were the second most abundant food component in the stomachs of *S. gibbosa* with their relative percentage proportion varying between 0.2% and 51% (mean of 14.2% for the 14 sample batches). However, in *S. albella* stomachs they ranked third in abundance with their relative percentage proportion varying between 0% to 29% (mean of 5.3% for the 14 sample batches). The abundance of these organisms in the stomachs varied considerably; for example, in the *S. albella* stomachs the relative percentage proportion was below 2% in nearly half of the examined batches of fish, but in the October and November samples they formed 29% and 24% respectively of the food composition. This tendency is also apparent in *S. gibbosa* stomachs, in that the relative abundance in the 14 batches of samples showed considerable fluctuations.

As for the frequency of occurrence of hyperiids as given by the number of stomachs containing them, in both *S. gibbosa* and *S. albella*, they ranked fifth in position with a frequency of 38.4% and 27.6% in the former and latter species of sardines respectively.

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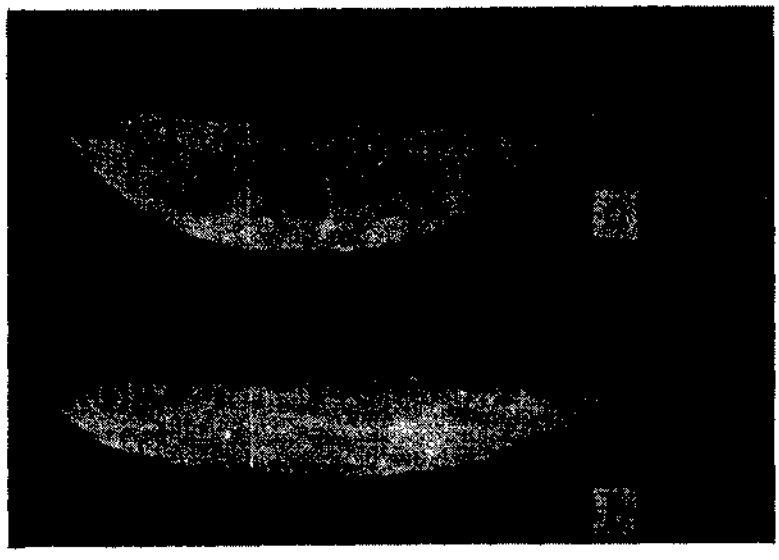

Fig. 1. a. *Sardinella albella* and b. *S. gibbosa*.

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The most frequent and abundant hyperiids in the stomachs were *Hyperia* spp., though the other types e. g. *Simorhynchotus antennarius* (Claus) and *Paratyphis parvus* Claus were also occasionally present in the stomachs.

The ostracod *Cypridina sinuosa* Müller was the second and third most important item of food in the stomachs of *S. albella* and *S. gibbosa* respectively. Its relative percentage abundance in *S. albella* stomachs varied between 0.4% and 69.7% (mean value of 13.0% for the 14 sample batches) and in *S. gibbosa* stomachs it ranged from 0.5% to 32.4% (mean value of 8.7% for the 14 sample batches). This ostracod was the second most frequently occurring organism with a percentage frequency of occurrence of 43.5% and 42.8% in the stomachs of *S. gibbosa* and *S. albella* respectively.

Observations on daytime inshore plankton samples suggest that *C. sinuosa* is a member of the night plankton and since it is known that clupeids stop feeding at night, it seems likely that under natural conditions this organism probably does not provide a significant contribution to the food of these sardines. However, Blaxter and Holliday (1963) report that Johnson (1939, a) and they, themselves in 1958 found feeding to take place in captive herring in moonlight (incident light intensity probably about 0.25 lux). Tropical fullmoon nights are very bright, illuminating the surface of the seas considerably, though the intensity and brightness of the incident light has not been measured. It is therefore possible that on these nights the sardines may be feeding, in which case *C. sinuosa* would also be consumed. *C. sinuosa* also appears to be a luminescent organism and it is therefore also likely that the light they produce may trigger a predatory action from the sardines. However, these suggestions clearly need to be tested by further observations.

Though the cyclopoid copepod *Oncea* spp. ranked 5th in importance as far as its relative percentage abundance in the stomachs of *S. gibbosa* is concerned, it seems more likely that the high mean value of 5.7%, compared to 1.4% in the case of the stomach contents of *S. albella*, is an arithmetical artefact resulting from the high percentage proportion value of *Oncea* spp. for the fish samples of November, 1969. More usual, the relative percentage abundance varied between 0% and 5% and 0% to 6% in the case of *S. gibbosa* and *S. albella* respectively.

The values of frequency of occurrence of stomachs with *Oncea* spp. also lend support to the relative unimportance of this group in the diet. In both *S. gibbosa* and *S. albella*, *Oncea* spp. rank 13th in position in the order of frequency of incidence as given by the number of stomachs containing them.

The harpacticoid copepods, *Macrosetella* and *Microsetella* together contributed from 0.05% to 18.4% (mean value of 3.4% for 14 samples) and 0.04% to 15.1% (mean value of 3.7% for the same number of samples) in the diet of *S. albella* and *S. gibbosa* respectively. In the frequency of occurrence order, they ranked 7th and 9th in *S. gibbosa* and *S. albella* respectively.

Several types of brachyuran megalopae were found in the stomach contents and their relative percentage proportion varied from 0% to 10.6% (with a mean of 3.5% for 14 samples) and 0% to 11.2% (with a mean value of 3.0% for 14 samples in *S. gibbosa* and *S. albella* respectively. 39.5% and 22.0% of the stomachs of the former and latter species of *Sardinella* contained megalopae in them.

TABLE 2. *Relative percentage composition of the main components of the stomach contents of* S. gibbosa *samples*

Organisms	14/3/69	18/4	21/4	20/5	12/6	12/8	16/9	10/10	4/11*	4/11*	15/12	9/1/70	9/2	12/3
C. sinuosa	9.9	29.0	32.4	2.1	7.8	0.5	1.4	3.7	0.6		5.8	17.1	10.0	2.3
Calanoidea	35.5	17.4	34.1	79.4	27.1	60.7	13.4	6.1	44.8	22.8	63.0	13.7	44.7	36.4
Oncea	4.7				1.9	3.6	1.0		9.0	57.1	0.7		1.5	1.6
Oithona	1.0			1.0	1.0	1.0	1.4	2.6		1.0		2.8	3.8	1.0
Corycaeus	1.8	1.0	1.0	1.0	2.3	1.0		1.0	1.0	1.4	10.4	7.0	4.6	4.7
Macrosetella / *Microsetella*	6.8	1.0	1.0	1.0	3.3	5.6	2.6	1.0	1.4	5.4	1.0	15.1	6.9	3.4
Euterpina	4.9	1.0	1.0		2.9	2.6	2.2	1.0	1.0		1.0	3.9	3.1	1.0
Gammaridea	2.1	1.0	6.4	4.0	1.0		1.0	4.4	1.0	1.0	1.0	1.0		1.0
Hyperiidea	2.1	22.4	0.2	5.7	38.5	3.6	51.0	20.2	26.5	1.0	6.6			22.4
Mysidacea	1.0	1.0	3.4		1.0		1.0	2.6			1.0			
Leptochela	1.0		1.0	6.0	2.3		2.8	37.0	1.2					2.1
Lucifer	3.9	1.0	1.0	4.5	1.0		1.7	2.6	1.0	1.0	1.1	12.3	1.5	1.0
Caridean larvae	2.1	3.4	8.0	1.4	4.9	1.5	3.4	3.2	1.2		1.0	1.0	13.9	2.1
Brachyuran zoeae	1.3	3.0	3.5	1.2	1.0	3.6	5.0	1.0	2.0		2.1	3.9	1.5	4.2
B. megalopae	6.0	6.2	2.2	1.9	2.9		8.4	10.6	3.2		1.0	1.4		4.9
Stomatopod larvae	1.8		1.0		1.0	1.0	1.4	1.0			1.0		1.0	1.0
Young bivalve	0.8	3.0	1.0	1.0		1.5	1.0	1.0	1.0	4.1	1.0	13.4	1.5	2.9
„ gastropoda	2.6	1.4	1.9	1.7		2.6	1.0	1.0	1.0	1.4	1.7	1.0	4.6	3.9
Atlantidae	2.1		1.0	1.0		1.0	1.0	1.0	1.0		1.0			
C. acicula	1.0	1.0	1.9	1.0		1.5	1.0	1.0	3.0		1.0			1.8
Larvacea	1.3			1.0		3.1	1.0	1.0						
Thaliacea	2.1						1.0	1.0			1.0			
Fish fry	1.0			1.0			1.0	1.0		2.2	1.0	1.0		
Chaetognatha	1.3					1.5	1.0							

* Samples obtained from different boats.

TABLE 3. *Relative percentage composition of the main components of the stomach contents of* S. albella *samples*

Organisms	17/2/69	14/3	21/4	20/5	12/6	20/6	12/8	20/8	16/9	6/10	4/11	9/1/70	9/2	12/3
C. sinuosa	69.7	3.0	43.0	4.5		9.6		2.4	9.5	7.2	1.0	10.6	14.3	5.7
Calanoidea	8.4	33.7	27.8	69.8	67.7	55.1	81.1	40.2	51.1	28.0	59.7	42.9	32.9	39.5
Oncea	1.0	6.0		1.1	6.5	3.2	1.2	1.6	1.0		1.0			2.1
Oithona	1.0	4.6				1.0	1.8	1.0	1.0	7.0	1.0	7.4	4.3	4.2
Corycaeus		5.1	2.0	2.3	8.6	4.3	1.2	7.6	1.0	2.0	2.1	2.7	3.4	10.9
Macrosetella }														
Microsetella }	1.0	18.4	1.0	1.0	2.1	3.2	3.0		1.0			6.9	1.2	9.9
Euterpina	1.0	5.1	1.0	2.6	6.5	3.2	3.0	1.7	1.0	6.0		4.8	2.2	3.1
Gammaridea	1.0		4.2					2.4	1.0	4.7				
Hyperiidea	1.0			1.9	1.0	2.1	1.8	9.4	1.0	29.0	24.0			2.6
Mysidacea	4.8		2.2					2.4	1.9	1.0			1.0	
Leptochela	1.1				1.0	1.0		2.5	12.5	1.0	1.0		1.6	4.7
Lucifer	1.0		1.0	1.0	1.0	2.1		2.4	1.0	1.0	1.0	2.7	1.9	1.1
Caridean larvae	1.3	1.0	10.9	4.2		1.1	1.2	9.0	2.8	4.5	1.0		11.2	1.1
Brachyuran zoeae	1.0	2.0	4.0	6.0	3.2	8.6		1.0	1.1	1.0	3.7	1.1	1.0	4.2
B. megalopae	1.6	3.0	1.0	3.0	1.0	1.0		11.0	2.1	2.0	2.7	1.1	11.2	1.1
Stomatopod larvae			1.0					1.0	3.5	1.0	1.0			
Young bivalve	1.6	7.1	1.0	1.0				1.2	1.0	1.0		5.3	1.9	3.7
„ gastropoda	6.8	2.0	1.0	1.0	1.0		1.8	1.3	1.0	1.0	1.0	3.7	4.0	3.7
Atlantidae	1.0	1.0						1.0	1.0		1.0			
C. acicula								1.0		1.0				
Larvacea	1.0							1.0	8.9			4.8	1.9	
Thaliacea											1.0			
Fish fry								1.0						
Chaetognatha							1.8	1.0	1.7		1.0			

TABLE 4. *Ranks of food items based on values of mean percentage abundance and percentage frequency of occurrence*

Food items	Mean relative percentage value for 14 samples of each species of fish				Percentage frequency of occurrence as given by the percentage number of stomachs containing the organism			
	S. gibbosa		*S. albella*		*S. gibbosa*		*S. albella*	
	%	Rank	%	Rank	%	Rank	%	Rank
Calanoidea	35.6	1	45.6	1	85.8	1	89.3	1
Hyperiidea	14.2	2	5.3	3	38.4	5	27.6	5
C. sinuosa	8.7	3	13.0	2	43.5	2	42.8	2
Oncea	5.7	4	1.4	14	18.3	13	16.4	13
Macro + Microsetella	3.7	5	3.4	6	31.5	7	20.1	9
Brach. megalopae	3.5	6	3.0	7	39.5	3	22.0	8
Leptochela	3.3	7	1.8	12	11.4	15	11.1	15
Caridean larvae	3.3	7	3.5	5	32.7	6	31.3	4
Corycaeus	2.6	9	4.1	4	29.1	8	33.2	3
Lucifer	2.4	10	0.9	15	23.7	11	13.6	14
Brach. Zoeae	2.3	11	2.6	9	38.7	4	27.3	6
Young bivalves	2.1	12	1.6	13	24.0	10	17.4	12
,, gastropods	1.6	13	1.9	11	28.5	9	18.0	11
Euterpina	1.6	13	3.0	7	21.0	12	22.9	7
Oithona	1.0	15	2.3	10	12.0	14	19.2	10

The caridean prawn *Leptochela*, was present in only seven of the 14 examined batches of *S. gibbosa* and in six of these batches its relative percentage proportion was below 3%. However, in the sample batch of October 1969, it formed 37% by number of the stomach contents, hence giving a high mean of 3.3% for the 14 batches of *S. gibbosa*. *Leptochela* was present in 10 of the 14 examined batches of *S. albella* though in most of these batches its relative percentage proportion was below 3%. However, the food of September 1969 batch contained 12.5% by number of *Leptochela*. The mean value of its relative percentage proportion in 14 batches of *S. albella* was 1.8%.

It is known from the results of planktonic studies that *Leptochela* is present in the plankton in small numbers most of the time and only occasionally becomes very abundant. The frequency of occurrence of this zooplankter in the stomachs of *S. gibbosa* and *S. albella* (11.4% and 11.1% respectively) also shows that it is not frequently encountered by the fish.

Because of the larger size of *Leptochela* (10-20 mm long) its nutrient value is probably higher compared to the smaller more abundant zooplankters that are consumed by the sardines.

Several types of larvae of bottom-living carideans were observed in the stomachs and their relative percentage proportion varied between 0% to 13.9% (with a mean of 3.3% for 14 batches) and 0% to 11.2% (with a mean of 3.5%) in the stomachs of *S. gibbosa* and *S. albella* respectively. Thirteen of the 14 batches of examined fish of each species contained caridean larvae and their frequency of occurrence was 32.7% and 31.3% in the stomachs of *S. gibbosa* and *S. albella* respectively.

The small cyclopoid copepods, *Corycaeus* spp. (length about 0.5 mm to 2 mm), ranged in their relative percentage proportion of the stomach contents, from 0.4% to 10.4% (with a mean of 2.6% for the 14 samples) and from 0.1% to 10.9% (with a mean of 4.1% for 14 samples) in *S. gibbosa* and *S. albella* respectively. In about half of the batches of *S. gibbosa* samples, the relative percentage value was below 2% and in about the same proportion of *S. albella* stomachs, the percentage proportion was below 3%. The relatively high percentage value of 10.4% (196 individuals of *Corycaeus* spp.) for the 15-12-69 batch of *S. gibbosa* seems to correspond with the December peak of *Corycaeus* in the plankton (Okera, 1971). 29.1% and 33.2% of the stomachs of *S. gibbosa* and *S. albella* respectively, contained *Corycaeus* spp.

The relative percentage proportion of the sergestid, *Lucifer* sp. in the stomach contents varied between 0.4% and 12.3% (mean of 2.4% for 14 samples) and 0% to 2.7% (mean of 0.9% for 14 samples) for *S. gibbosa* and *S. albella* respectively. In about half of the samples of both *S. gibbosa* and *S. albella*, *Lucifer* formed less than 1% of the stomach contents; and as for its frequency of occurrence, 23.7% and 13.6% of the stomachs of *S. gibbosa* and *S. albella* respectively contained this crustacean. Owing to its large size however, its nutritional value may be higher compared to the smaller food items consumed by the sardines.

In the case of brachyuran zoeae, their relative percentage proportion in the stomachs of *S. gibbosa* varied between 0% and 4.2% (with a mean of 2.3% for 14 samples) and in *S. albella* stomachs, it ranged from 0% to 6% (with a mean of 2.6% for 14 samples). They occurred in 38.7% and 27.3% of the stomachs of *S. gibbosa* and *S. albella* respectively.

Besides the above mentioned crustaceans, two other copepods, namely *Euterpina* and *Oithona* spp. were relatively important in the diet. The relative percentage proportion of *Euterpina* varied between 0% and 4.9% (with a mean of 1.6% for 14 samples) and 0.1% to 6.5% (with a mean of 3% for 14 samples) in the stomach contents of *S. gibbosa* and *S. albella* respectively. The frequency of occurrence of *Euterpina* as given by the percentage proportion of stomachs containing them was 21.0% in *S. gibbosa* and 22.9% in *S. albella*.

The relative percentage proportion of *Oithona* spp. varied between 0% and 3.8% (with a mean of 1.0% for 14 samples) and 0% to 7.4% (with a mean of 2.3% for 14 samples) in the stomach contents of *S. gibbosa* and *S. albella* respectively. However, in about half of the 14 samples of either species of sardine, the relative percentage proportion was less than 1%. The frequency of occurrence of this cyclopoid copepod was also low being only 12.0% and 19.2% in *S. gibbosa* and *S. albella* respectively.

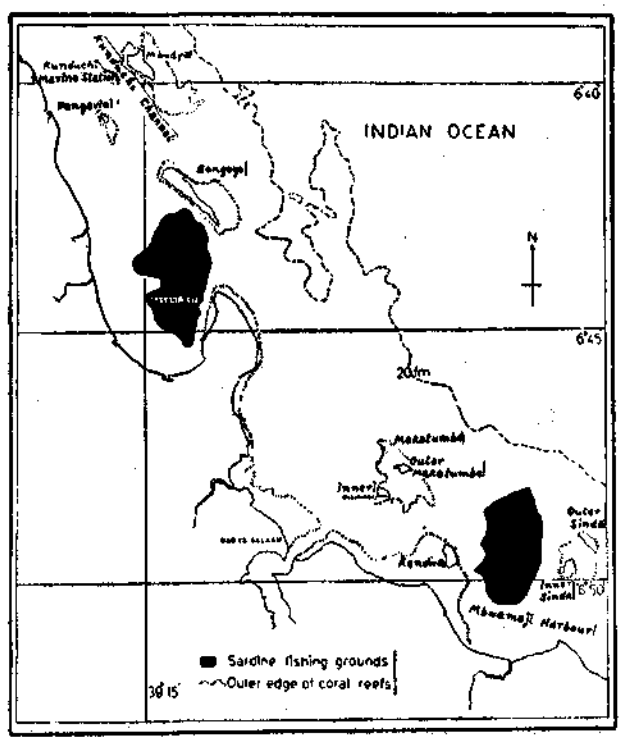

Fig. 2. Map of the Dar es Salaam Coast showing the fishing grounds and adjacent areas.

Several types of postlarval stages of bivalves (0.2-0.9 mm long) and gastropods (0.7-3 mm long) were the only non-crustacean that formed a regular and relatively significant proportion of the sardines' diet. The relative percentage proportion of young bivalves varied from 0% to 13.4% (with a mean of 2.1% for 14 samples) and 0% to 7.1% (with a mean of 1.6% for 14 samples) in the stomach contents of *S. gibbosa* and *S. albella* respectively. However, in about half of the samples of both *S. gibbosa* and *S. albella*, the relative percentage proportion of postlarval

bivalves was less than 1%. The frequency of *S. gibbosa* and *S. albella* stomachs containing these molluscs was 24.0% and 17.4% respectively.

Postlarval stages of gastropods ranged in their percentage proportion from 0% to 4.6% (with a mean of 1.6% for 14 samples) and 0% to 6.8% (with a mean of 1.9% for 14 samples) in *S. gibbosa* and *S. albella* stomachs respectively. In their frequency of occurrence, 28.5% and 18.0% of the stomachs of *S. gibbosa* and *S. albella* respectively contained these organisms.

The above fifteen groups of zooplankters were the more regular and abundant components of the stomach contents of both *S. gibbosa* and *S. albella* and Table 4 summarises the foregoing account by giving the values of the mean relative percentage proportion and the frequency of occurrence of these 15 groups of zooplankters in the stomach contents of the two species of sardines. For the purposes of the calculation of Kendall's coefficient of rank correlation, Table 4 also includes the ranks of these food items, based on both the values of the mean percentage abundance and the percentage frequency of occurrence.

The value of Kendall's coefficient of concordance (tau) calculated on the basis of rankings derived from the mean relative percentage abundance of the above food items in the stomachs of *S. gibbosa* and *S. albella* is +0.36 and the normal deviate T as calculated from the formula given by Mill (1965) is 1.83. These values show that there is a significant positive correlation between the main types of food items consumed by *S. gibbosa* and *S. albella*. The degree of concordance of rankings based on the percentage frequency of occurrence was not calculated, although inspection of the figures show that there may just as well be a positive correlation here.

The less abundant and infrequent items of food

Evadne

This cladoceran occurred in fewer numbers and were recorded in only three batches of each species of sardine. Table 5 gives the total number of *Evadne* in the stomachs of fish obtained on the indicated dates.

TABLE 5. *Number of* Evadne *in the stomachs*

Date	*S. gibbosa*	*S. albella*
17/ 2/69	—	4
14/ 3/69	2	–
21/ 4/69	1	1
15/12/69	18 (0.95%)	–
9/ 1/70	–	1

Euconchoecia chierchiae

This ostracod was also in small numbers and Table 6 shows the total number recorded in the stomachs of fish collected on the indicated dates.

TABLE 6. *Number of* E. chierchiae *in the stomachs*

Date	*S. gibbosa*	*S. albella*
17/ 2/69		1
21/ 4/69	1	–
20/ 5/69	2	1
18/ 6/69	–	4
16/ 9/69	1	1
15/12/69	6	–
9 /1/70	3	8
9/ 2/70	–	2

Other ostracoda

Apart from *C. sinuosa* and *E. chierchiae*, other ostracods namely, *Propontocypris* cf. *lobodonta*, *Cycloleberis* sp., *Cypridinoides minuta* and *Synasterope* cf. *oculata* were also occasionally encountered in the gut.

Sapphirina and other cyclopoida

Only 2 specimens of *Sapphirina* were encountered in the 12–8–69 batch of *S. albella* and a single specimen in 14-3-70 batch of *S. gibbosa*. A few more unidentified cyclopoids were also seen on several occasions in the stomachs but in quite small numbers.

Clytemenestra, ?Metis and other harpacticoids

Five and one specimens of *Clytemenestra* were seen in the 20-8-69 and 9-2-70 batches respectively of *S. albella* and a total of four, three and one specimens were encountered in the *S. gibbosa* batches of 12-8-68, 15-12-69 and 9-1-70 respectively. Only one *?Metis* was found in the 14-3-69 batch of *S. albella*. A few other unidentified harpacticoids were also present in the stomach contents.

Cirripede larvae

Single specimens of cirripede nauplii were present in the 12-6-69 batch of *S. albella* and 12-8-69 batch of *S. gibbosa*. The cypris stage on the other hand was commoner and Table 7 showing the numerical and temporal occurrence in the stomachs, indicates that the cypris was relatively abundant in the stomachs during April and May compared to the samples of other months.

TABLE 7. *Number of cirriped cypris in the stomachs*

Date	*S. gibbosa*	*S. albella*
14/3/69		1
18/4/69	38	–
21/4/69	9	5
20/5/69	3	2
16/9/69	1	–
10/10/69	1	–
15/12/69	1	–
12/3/70	1	–

Mysidacea

Anchialus (or *Anchialina?*) was the principle mysid in the stomach contents. As Table 8 indicates, at times the number of mysids in the stomachs was quite high and because of their large size (about 2 to 8 mm long), it is possible that their nutritional value may also be quite high.

Cumacea

These crustacenas (about 5-8 mm long) were present in very small numbers (Table 9) in the stomachs in several batches of the two species of sardines. However, further identification of the several types observed, was not attempted.

TABLE 8. *Number of mysids in the stomachs*

Date	*S. gibbosa*	*S. albella*
17/2/69		119 (4.7%)
14/3/69	4 (1%)	
18/4/69	6	
21/4/69	34 (3.4%)	13 (2.2%)
12/6/69	1	
20/8/69		22 (2.4 %)
16/9/69	3	33 (1.9 %)
6/10/69		4 (0.6 %)
10/10/69	26 (2.6%)	
15/12/69	6 (0.3%)	
9/2/70		2

TABLE 9. *Number of cumaceans in all the stomachs*

Date	*S. gibbosa*	*S. albella*
17/2/69	–	2
14/3/69	1	–
21/4/69	6	3
12/6/69	2	–
18/6/69	–	1
20/8/69	–	4
16/9/69	6	4
6/10/69	–	5
10/10/69	10	–
4/11/69	9	12
9/2/70	–	2

Isopoda

Usually, one or two cryptoniscid larvae (0.5 mm-2 mm long) of parasitic isopods were encountered in the gut contents of several batches of the sardines and the maximum number recorded was five from the 20-5-69 batch of 25 specimens of *S. gibbosa*. Only a single specimen of an adult-like isopod was present in the 21-4-69 batch of *S. albella*.

Amphipoda-Gammaridea

The most regularly occurring gammaridean in the stomachs of the sardines was *Synopia variabilis* Spandl though several other types were also occasionally present. Table 10 shows that at times, the sardines consume the gammarideans in relatively large numbers. Unlike the hyperiid amphipods, the total number of gammarideans in any batch of fish examined did not exceed sixtyfour.

TABLE 10. *Number of gammarideans in all the stomachs*

Date	*S. gibbosa*	*S. albella*
17/2/69		24 (1.0%)
14/3/69	8 (2.1%)	–
18/4/69	5	–
21/4/69	64 (6.4%)	25 (4.2%)
20/5/69	4	–
12/6/69	7	–
20/8/69	–	22 (2.6%)
16/9/69	4	10 (0.6%)
6/10/69	–	33 (4.7%)
10/10/69	44 (4.4%)	–
4/11/69	4	5
9/2/70	1	–
12/3/70	1	–

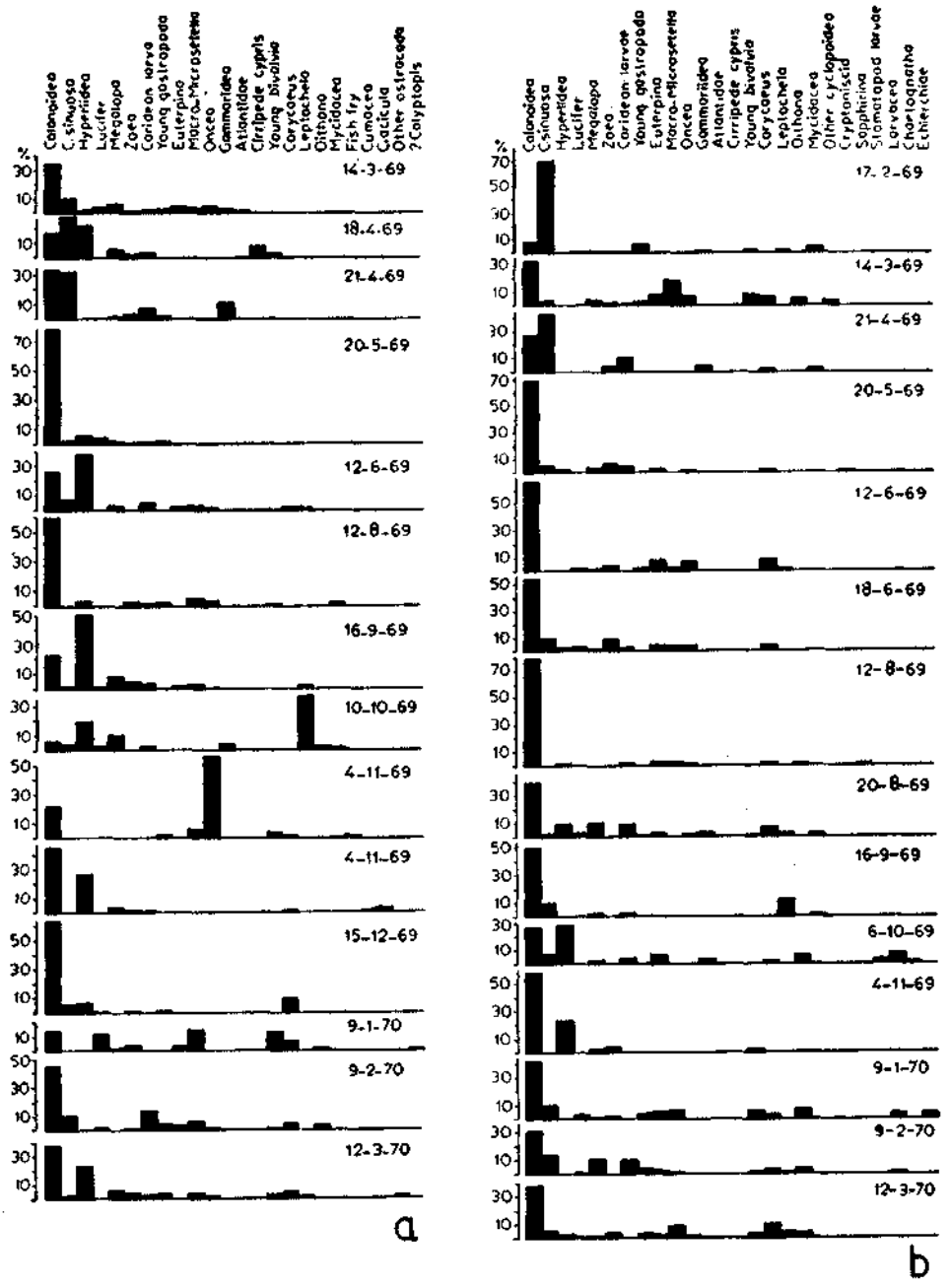

Fig. 3. Histograms of the relative percentage composition of various zooplanktonic organisms in the stomach contents of the fourteen samples of fish examined during the period March 1969 to March 1970. a. *Sardinella gibbosa* and b. *S. albella*.

Euphausiacea

Only four adult euphausiids were recorded from the stomachs of 16-9-69 batch of *S. albella*, which is not at all surprising because of the near total absence of this group of crustaceans from the plankton samples collected from the fishing grounds. What has been identified as the calyptopis stage of euphausiids was however present in several batches of *S. gibbosa* and *S. albella*, though in very small numbers, mostly a single specimen from the stomach contents of all the fish from a particular sample.

Anomuran zoeae and post-zoeae

These larvae appeared several times in the stomach contents of both the *Sardinella* species though at no time were they in any significant numbers.

Stomatopod larvae

One or two larvae of stomatopods, about 8 mm-10 mm long, were present in the stomach contents of several batches of fish though the 16-9-69 batches of *S. albella* and *S. gibbosa* had in their stomachs 59 and 15 specimens respectively of stomatopod larvae.

Scyllarid larvae

The phyllosoma of bottom-living scyllarids were observed in the stomach contents of *S. gibbosa* and *S. albella* samples obtained on 16-9-69, but a total number of only four and one specimen were present in the stomachs of the former and latter species of fish respectively.

Chaetognatha

It is probable that all the chaetognaths encountered in the stomachs were *Sagitta* spp. although the specimens from the stomachs were not in identifiable state. Table 11 gives the numerical and temporal occurrence of these carnivorous zooplankters in the stomachs and it can be seen that in only one instance was their number relatively large.

TABLE 11. *Number of Chaetognaths in all the stomachs*

Date	*S. gibbosa*	*S. albella*
14/3/69	5	–
12/8/69	3 (1.5%)	3 (1.8%)
20/8/69	–	1
16/9/69	1	29 (1.7%)
4/11/69	–	5
9/ 2/70	–	1

Creseis acicula Rang

This thecosome pteropod (length of their conical shell varying between 2 to 10 mm) occurred in small numbers as is shown in Table 12, though some specimen of *S. gibbosa* examined during June and July 1968, had their stomachs gorged with this mollusc. It is also interesting to note that of the two batches of *S.gibbosa* obtained on 4-11-69, from two different boats (both having fished in the Sinda - Kendwa grounds), specimens from only one of them had consumed *C. acicula*.

TABLE 12. *Number of* C. acicula *in all the stomachs*

Date	*S. gibbosa*	*S. albella*
14/3/69	1	–
18/4/69	2	–
21/4/69	19 (1.9%)	–
20/5/69	2	–
12/8/69	3 (1.5%)	–
20/8/69	–	1
16/9/69	1	–
6/10/69	–	4
10/10/69	11	–
4/11/69	15 (3.0%)	–
15/12/69	1	
12/3/70	7 (1.8%)	

Atlantid heteropod

This is the only other planktonic mollusc which was present in the stomachs of both the species of sardine. It is similar to Fig. 135a of Wickstead (1965), and it was also taken in the plankton regularly but in quite small numbers (Okera, 1971). Table 13 gives the numerical and temporal occurrence of these organisms in the gut and it can be seen that in more than half of the fish samples, it occurred in only one or two. The diameter of those encountered in the gut ranged between 2 mm and 4 mm.

TABLE 13. *Number of atlantid heteropod in all the stomachs*

Date	*S. gibbosa*	*S. albella*
17/2/69	–	5
14/3/69	8 (2.1%)	1
21/4/69	1	–
20/5/69	9	–
12/8/69	2	–
20/8/69		3
16/9/69	2	1
10/10/69	6	
4/11/69	2	2
15/12/69	17 (0.9%)	
12/3/70	1	1

Larvacea

Though quite common in the plankton (Wickstead, 1965; Okera, 1971), Table 14 shows that when present in the stomach contents, they are most of the time in insignificant numbers. Because of their abundance in the plankton, this observation is surprising and it is not likely that these zooplankters, because of their small size (majority *ca* 1 mm long), were missed in the examination of the gut contents.

TABLE 14. *Number of larvaceans in all the stomachs*

Date	*S. gibbosa*	*S. albella*
17/2/69		4
14/3/69	5	–
20/5/69	–	8
18/6/69	1	
12/8/69	–	6 (3.1%)
20/8/69	2	
16/9/69	151 (8.9%)	1
10/10/69		1
4/11/69	–	1
9/ 1/70	9 (4.8%)	
9/ 2/70	6 (1.86%)	
12/3/70	1	

Thaliacea

From a few to several zooids were encountered in the stomachs of the two species of sardines. *S. albella* stomachs contained 5 and 1 zooid on 16-9-69 and 4-11-69 sample respectively, and stomachs of *S. gibbosa* of 14-3-69, 16-9-69, 10-10-69 and 15-12-69 contained 8, 2, 6 and 12 zooids respectively.

Fish egg and fry

A few fish eggs were recorded from the stomachs of both the species (Table 15) but identification of these were not attempted. Most of the fish fry recorded (Table 15) were engraulids (about 10 mm-15 mm long) and some clupeids (about 7 mm-15 mm long); identification of these fries was facilitated by the work of Delsman (1926) and John (1951).

TABLE 15. *Number of fish eggs and larvae in all stomach*

Date	Fish eggs		Fish larvae	
	S. gibbosa	*S. albella*	*S. gibbosa*	*S. albella*
14/3/69			4	
18/4/69	6			
20/5/69	1			
12/8/69	1			
20/8/69		2	1	5
16/9/69		1	3	4
10/10/69			6	
4/11/69	3	1	5	
15/12/69	1		1	
9/1/70			1	

Polychaeta

Only a single specimen from each of the samples of *S. albella* obtained on 20-5-69, 20-8-69 and 9-1-70 contained a polychaete and the same was true for *S. gibbosa* obtained on 21-4-69, 4-11-69 and 15-12-69. Two specimens of *S. gibbosa* from the 14-3-69 sample contained in their stomachs one polychaete each. Except for the specimens of alciopids, the other polychaetes which were present in the stomachs were not identifiable. The alciopid specimens were about 3 to 4 cm long.

Siphonophoran nectophore

Only one nectrophore was encountered in the stomach of a specimen of *S. gibbosa* from the 12-8-69 batch.

The food of the different size groups of fish

The 9-2-70 samples of both *S. gibbosa* and *S. albella* which contained mostly fish of 6 cm to 7 cm S. L., showed that the qualitative composition of their stomach contents was very similar to those fishes belonging to the higher size groups. These organisms ranged from the very minute ones such as *Euterpina* (about 0.8 mm long) and *Oithona* (less than 1 mm long) to the relatively larger forms such as *Lucifer* (about 10 mm long) and caridean larvae (about 8 mm long). These observations suggest that *S. gibbosa* and *S. albella* specimens ranging in size from about 6 cm to 12.5 cm S. L. can consume a fairly broad spectrum of sizes of zooplanktonic prey, though it is quite likely that grazing on the larger zooplankters *e. g.* mysids or *Lucifer* or clupeoid fry is probably 'easier' for the larger *S. gibbosa* and *S. albella* than the smaller individuals.

It is probable however, that larvae and early juveniles of these species of sardines may be feeding mostly on minute organisms of the plankton, the size of the food organism taken tending to increase with the size of the larvae (Blaxter and Holliday, 1963). On the other hand, Iizuka (1962, quoted from Blaxter and Holliday, 1963) working on *Clupea pallasii* larvae reported an increase in mouth size with growth but no great change in size of food taken by the larvae. Further observations on the diet of individuals of *S. gibbosa* and *S. albella* less than 6 cm S. L. would be helpful to clarify the situation.

The nature of the food items consumed by the sardines and their mechanism of feeding

Both *S. gibbosa* and *S. albella* ranging in size between 6 and 13 cm consumed similar food items and these varied considerably in size range. Zooplankters such as *Oithona, Corycaeus, Oncea* and *Euterpina* are usually between 0.5 to 1.0 mm long; the majority of the calanoids vary in length between 0.7 and 1.5 mm and *Cypridina sinuosa* ranges from about 1 to 2 mm long. Hyperiids are still slightly larger (3 to 5 mm) and the larger zooplankters such as *Lucifer* (8 to 10 mm), mysids (4 to 8 mm), *Leptochela* (10 to 20 mm) and clupeoid larvae (20 to 30 mm) are also consumed in 'appreciable' numbers when they are abundant. The detailed facie of the above mentioned organisms as well as others that have been found in the stomachs is very variable; *e. g.* the differences in shape between a phyllosoma or a stomatopod larvae and a calanoid copepod or a *Macrosetella.* Hence zooplanktonic organisms falling within a certain broad spectrum of size and shape are consumed by sardines and the latter are therefore relatively 'flexible' in their selection of food items as far as size and shape of the prey is concerned. In connection with this observation the ubiquitous question of the mechanism of feeding in clupeids arises. The foregoing account suggests that it is improbable that the larger and more mobile zooplanktonic organisms such as *Lucifer,* fish larvae, and *Leptochela* are attained through filter-feeding. The capture of these organisms probably involve definite acts of seizure (Muzinic, 1960) with the jaws followed by gulping. The smaller organisms such as *Oncea, Oithona* and *Corycaeus* are probably obtained by filter feeding together with phytoplankton such as *Coscinodiscus* and *Fragilaria* which have been reported as constant items of food in the Indian *S. albella* (Nair, 1960). Lack of time did not permit an investigation in these two species of sardines of the epibranchial organs which are thought to enable fish to feed efficiently on micro-organisms by filtration (Iwai, 1954; Nelson, 1967; Bertmar and Stromberg, 1969).

Certain zooplanktonic groups such as ctenophores and hydromedusae were not recorded at all from the stomach contents and only a single siphonophoran bell was observed from the total number of stomachs examined. This does not seem to be due to their low numbers for infrequent zooplankters such as phyllosoma larvae of scyllarids and stomatopod larvae did occasionally appear in the stomach contents. Several possible reasons may be put forward to explain this observation, *viz*; unpalatability, unsuitable shape and transparency. Each of these suggestions need to be experimentally tested.

COMPARISON OF THE PRESENT RESULTS WITH THOSE FROM OTHER PARTS OF THE INDIAN OCEAN

Nair (1960) mentions that several workers (Devanesan, 1932; Devanesan and Chidambaram, 1948; Ganapati and Rao, 1957) have investigated the food of *S. gibbosa* in Indian coastal waters and John (1939), Chacko (1956), Chacko and

Mathew (1956), Devanesan and Chidambaram (1948) and Vijayaraghavan (1953), have worked on the food of *S. albella* in the same region. In Singapore waters, Tham (1950; quoted from Li Kwan-Ming) has worked on the food of *S. fimbriata* (Valenciennes) and *S. perforata* (Cantor). The lists of food items found in the guts of *S. gibbosa, S. albella* and *S. fimbriata* and *S. perforata* (Table 16) are compiled from the work of the above authors as quoted from Nair (1960) and Li Kwan-Ming (1960).

TABLE 16. *Food items reported by various authors as being found in the guts of four species of Sardinella*

S. gibbosa	*S. albella*	*S. fimbriata and S. perforata*
Trichodesmium	*Trichodesmium*	Phytoplankton
Diatoms	*Fragillaria*	Brachiopod larvae
Dinoflagellates	*Coscinodiscus*	Gastopod larvae
Crab larvae	*Paracalanus*	Bivalve larvae
Copepoda (including *Undinula, Centropages, Eucalanus, Macrosetella* and *Oncea.*)	*Acartia*	*Sagitta*
	Pseudodioptomus	*Evadne*
	Othona	Ostracods
Lucifer	*Corycaeus*	Copepods
Foraminifera	*Euterpina*	Amphipods
Sagitta	Fish eggs	*Squilla* larvae
Larval bivalves	*Sagitta*	Penaeid larvae
Young prawns	*Lucifer*	*Lucifer*
Larvae of *Acetes & Alpheus*	Crab larvae	Acetes
Gastropod larvae	*Mesopodopsis*	*Leptochela*
Postlarvae of *Anchoviella*	*Acetes*	Alpheid larvae
	Squilla larvae	Brachyuran larvae
		Decapod larvae
		Polychaeta
		Cypris larvae
		Mysids
		Stolephorus larvae

The sardines whose stomach contents were examined in this work, were caught in the light fishery and consequently comparison with any other work has to take this factor into consideration. For the stomach contents will now reflect the food of the sardine which has been feeding on night plankton that probably changes significantly under the influence of artificial light and secondly the feeding 'activity' of a sardine at night and under the influence of artificial light may be different from daytime feeding fish.

However, when the lists in Tables 2, 3 and 16 are compared, it can be seen that the sardines from East African waters are feeding on generally the same types of zooplanktonic organisms as sardines from other parts of the Indian Ocean. It is also interesting to note that none of the above workers (as quoted from Nair, 1960 and Li Kwan-Ming, 1960) have recorded larvacea, ctenophora, hydromedusae and Siphonophoran nectophores from the gut contents. Further laboratory work is needed to observe the reactions of sardines on encountering these organisms.

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