

Food and feeding habits of oil sardine *Sardinella longiceps* from Ratnagiri coast off Maharashtra India

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Received 07 August 2017; revised 08 January 2018

The food of oil sardine, *Sardinella longiceps* caught off Ratnagiri, Maharashtra, was studied using 917 specimens obtained randomly from commercial catches. The fish was found to be predominantly a plankton feeder, consuming diatoms, dinoflagellates, zooplankton, blue-green algae, and unrecognizable matter. Diatoms formed the most important group followed by zooplankton and dinoflagellates. Unrecognizable matter comprising mud, fish scales and detritus were observed in the stomach contents throughout the year.

[Keywords: Diatoms, Oil sardine, *Sardinella longiceps*, Ratnagiri, Index of relative importance]

Introduction

The oil sardine, *Sardinella longiceps* Valenciennes 1847 is by far the most important single-species fishery that contributes to the fisheries wealth of not only India but the entire Indian Ocean. It has traditionally played a crucial role in the marine fishery economics of India. It has a wide distribution along the coasts of Seychelles, Somalia, Africa, Gulf of Aden, Red Sea, Gulf of Oman, Persian Gulf, Sri Lanka, Malaysia, Vietnam, India, Pakistan, Indonesia, and Philippines¹. In the Indian peninsula, the resource is predominant along the south-west coast between 8° N and 16° N latitudes, covering Kerala, Karnataka, Goa and southern part of Maharashtra, though stray catches of the species are landed along the coasts of Tamil Nadu, Andhra Pradesh, and even Orissa on the east coast as well². Along the west coast, large shoals of oil sardine occur from Ratnagiri in the north to Quilon in the south.

Materials and Methods

For the present investigation, 917 fresh specimens of *S. longiceps* were collected at random from Mirkarwada Landing Centre of Ratnagiri Maharashtra, India, from October, 2010 to May, 2012. The specimens were brought in ice packs to the laboratory for further analysis. Prior to analysis, the specimens were cleaned and wiped properly. To examine the food, fish were dissected and the weight

and length of the whole gut and the stomach were recorded after wiping off the moisture. The condition of the stomach with respect to the food was also noted.

The stomach of all the specimens were cut open and the food was removed. The weight of the food was determined by the method given by Kagwade³. The stomach contents were made up to a known volume (10 cc) by adding 5% formaline and stored for analysis later. At the time of examination, 1 cc from this mixture was taken on a counting chamber and the various food items were examined and counted under a microscope. Each food item was identified to the genus level, and wherever possible, attempts were made to identify the food up to the species level. As the oil sardine is a plankton feeder, the points (volumetric) method⁴ was followed in the present work. Each food item was allotted a certain number of points based on its volume.

The occurrence method was also employed to indicate the relative importance of different food items. In this method, the number of stomachs containing a particular item of food is expressed as a percentage of the total number of guts examined⁴. Depending on the percentage of stomachs when a particular food item occurred in the diet of the fish, the different items were grouped into 'very common' (76-100%), 'common' (51-75%), 'frequent' (26-

50%), and 'rare' (1-25%). In analysing the food of the fish, the method of index of preponderance⁵ was also followed. Here, since the volume of the individual plankters could not be estimated by volume displacement method, the volume calculated by points) (volumetric) method⁴ was used in evaluating the index of preponderance⁶.

Results

Food composition

The month-wise composition of food items encountered in the diet of *S. longiceps* based on points method is presented as food item-wise (Table 1) and group-wise (Table 2 and Fig. 1). It indicated that diatoms, blue-green algae, dinoflagellates, zooplankton and unrecognizable matter were the main food items consumed by the fish.

Diatoms formed the most dominant group and was represented by 20 genera, which included: *Asterionella japonica*, *Aulacodiscus* sp., *Bacillaria* sp., *Bacteriastrum* spp., *Biddulphia mobiliensis*, *B. sinensis*, *B. favus*, *Cerataulina pelagica*, *Chaetoceros* spp., *Coscinodiscus excentricus*, *C. lineatus*, *C. radiatus*, *Ditylum sol*, *Lithodesmium undulatum*, *Fragilaria oceanica*, *Nitzschia closterium*, *N. seriata*, *Planktoniella sol*, *Pleurosigma* spp., *Rhizosolenia* spp., *Skeletonema costatum*, *Thalassionema nitzschioides*, *Thalassiosira* spp., *Thalassiothrix* sp., *Triceratium* sp., and *Triceratium malleus*. The bulk of the food comprised diatoms in all the months except January (25.73%), April (41.04%) and December (17.28%). In the other months, the percentage composition of diatoms ranged from 50.17% in August to 83.04% in May. *Coscinodiscus* spp. was the most dominant food item in October (41.70%) and August (26.08%), *Nitzschia* spp. in November (42.33%), *Rhizosolenia* spp. in September (40.72%), *Skeletonema costatum* in May (56.52%), *Thalassiosira* spp. in March (29.65%), and *Triceratium* spp. in February (22.06%). *Coscinodiscus* spp., *Nitzschia* spp., *Pleurosigma* spp., *Rhizosolenia* spp. and *S. costatum* were the most dominant diatoms, while *Aulacodiscus* sp, *Bacteriastrum* spp., *Ditylum sol*, *Lithodesmium undulatum*, *Planktoniella sol* and *Thalassiothrix* were the least dominant.

Zooplankton formed the second most important group in the diet and included copepods, fish eggs, Lucifer, nauplii, Tintinnids, Foraminifera (*Globigerina* spp.), and bivalve larvae. The percentage composition of zooplankters was higher in

December (76.26%), January (67.21%) and April (55.12%). Copepods were the most dominant zooplankters throughout the year (except in August (0.86%) forming the bulk of the stomach contents in December (68.71), January (59.88%) and April (54.37%). Copepods were represented by *Cyclops* spp., *Calanus* spp., *Pseudocalanus* spp., *Paracalanus* spp., *Microsetella* spp., and *Eurytemora* spp. Fish eggs were encountered in the diet from August (14.16%) to November (0.32%). Nauplii formed an important constituent of the diet in September (9.45%), February (7.79%) and January (5.38%). Tintinnids were represented by *Codonella* spp., *Rhabdonella* spp., and *Codonellopsis* spp. and were encountered in very small numbers throughout the year except in April, August and December. Foraminifera, represented by *Globigerina* spp., were recorded in small numbers.

Dinoflagellates belonging to six genera were represented by *Ceratium longipes*, *C. furca*, *C. fusus*, *C. tripos*, *C. macroceros*, *Dinophysis acuta*, *D. tripos*, *D. caudata*, *D. miles*, *Glenodinium* spp., *Ornithocercus* sp., *Peridinium* spp., and *Porocentrum micans*. *Ceratium* spp. was the most abundant dinoflagellate comprising 17.96% in August, 10.94% in October and 8.14% in November. *Peridinium* spp. was observed in all the months in smaller quantity, ranging from 0.14% in October to 3.32% in November.

Unrecognizable matter/scales, including mud, fish scales and detritus was observed throughout the year in varying quantity. Blue-green algae,

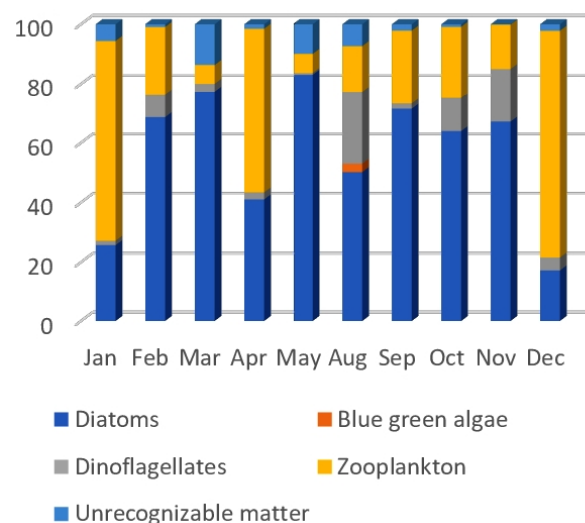


Fig. 1 — Bar diagram showing the monthly composition of different groups in the diet of *S. longiceps*.

represented by *Trichodesmium theibautii* was encountered only in August (2.81%).

The monthly percentage frequency of the occurrence of different food items in the stomachs of the fish examined in a month are presented in Table 3

and Figure 2. It shows that diatoms and zooplankters formed two major components among the food consumed by the fish. *Coscinodiscus* spp. appeared in the food throughout the year with monthly percentage frequency of occurrence ranging from 66.67% (April)

Table 1 — Month-wise percentage composition of food items in the diet of *S. longiceps*

Group	Food item	Jan	Feb	Mar	Apr	May	Aug	Sep	Oct	Nov	Dec
Diatoms	<i>A. japonica</i>	0.21	0.29	0.82	0.85	1.24	0.09	-	-	-	0.07
	<i>Aulacodiscus</i> sp.	-	-	1.09	-	-	-	-	-	0.08	-
	<i>Bacillaria</i> sp.	3.07	0.33	7.36	2.99	0.69	0.17	0.14	-	0.77	0.82
	<i>Bacteriastrum</i> spp.	-	-	-	-	-	0.09	-	0.19	0.04	-
	<i>Biddulphia</i> spp.	0.07	2.89	0.14	-	1.98	0.17	2.56	0.47	2.70	-
	<i>C. pelagica</i>	-	17.81	-	-	-	-	-	-	-	-
	<i>Chaetoceros</i> spp.	0.10	0.12	0.14	0.85	-	1.08	0.50	0.42	0.08	1.43
	<i>Coscinodiscus</i> spp	6.28	6.43	8.18	9.38	11.50	26.08	18.19	41.70	6.93	8.71
	<i>Ditylum sol</i>	-	-	-	-	-	0.60	0.28	-	-	-
	<i>L. undulatum</i>	-	-	-	-	0.30	-	-	0.09	-	-
	<i>F. oceanica</i>	-	1.65	21.81	14.71	1.39	-	0.57	-	3.06	-
	<i>Nitzschia</i> spp.	1.47	-	0.89	0.32	0.25	4.92	3.55	9.01	42.33	0.20
	<i>Planktoniella sol</i>	0.35	-	-	-	-	0.43	1.78	-	-	-
	<i>Pleurosigma</i> spp.	12.22	15.22	1.70	0.53	6.94	-	1.07	2.59	6.45	5.44
	<i>Rhizosolenia</i> spp.	1.26	0.99	1.02	-	0.45	12.44	40.72	1.84	0.18	0.61
	<i>S. costatum</i>	0.42	-	3.00	7.68	56.52	-	-	-	1.37	-
	<i>T. nitzschioides</i>	-	0.66	1.57	2.67	0.55	2.16	0.28	3.11	2.62	-
	<i>Thalassiosira</i> spp.	0.17	-	29.65	-	0.50	-	-	3.54	0.30	-
	<i>Thalassiothrix</i> spp.	0.10	0.16	-	-	-	1.94	-	-	0.20	-
	<i>Triceratium</i> spp.	-	22.06	-	1.07	0.74	-	1.78	0.94	-	-
Total	25.73	68.62	77.37	41.04	83.04	50.17	71.43	63.92	67.12	17.28	
Blue green algae	<i>T. theibautii</i>	-	-	-	-	-	2.81	-	-	-	-
	Total	-	-	-	-	-	2.81	-	-	-	-
Dinofla-gellates	<i>Ceratium</i> spp.	-	3.13	-	-	-	17.96	0.57	10.94	8.14	0.27
	<i>Dinophysis</i> spp.	0.10	1.98	1.64	1.28	-	0.39	0.43	-	4.84	1.43
	<i>Glenodinium</i> spp.	-	0.49	0.14	0.43	-	-	0.14	0.09	-	0.54
	<i>Ornithocercus</i> sp.	0.10	0.49	-	0.32	-	-	0.43	-	1.03	1.43
	<i>Peridinium</i> spp.	0.63	1.36	0.61	0.32	0.59	1.30	0.21	0.14	3.32	0.20
	<i>P. micans</i>	0.63	0.33	0.27	-	-	4.66	-	-	0.56	0.41
	Total	1.47	7.79	2.66	2.35	0.59	24.31	1.78	11.17	17.89	4.28
Zoo-plankton	Copepoda	59.88	13.61	6.13	54.37	4.96	0.86	12.08	14.62	12.29	68.71
	Fish eggs	-	-	-	-	-	14.16	2.27	1.13	0.32	-
	Lucifer	-	0.29	-	0.75	0.35	-	-	-	0.28	1.43
	Nauplii	5.38	7.79	-	-	-	-	9.45	2.31	1.55	1.90
	Tintinnids	0.42	0.99	0.20	-	0.74	-	0.21	4.11	0.42	-
	Foraminifera	1.54	-	-	-	0.40	0.35	0.28	1.89	-	3.54
	Bivalve larvae	-	-	-	-	-	-	0.36	-	-	0.68
Total	67.21	22.68	6.34	55.12	6.45	15.37	24.66	24.06	14.87	76.26	
Unrecognizable matter/ scales etc.	5.59	0.91	13.63	1.49	9.92	7.34	2.13	0.85	0.12	2.18	

Table 2 — Group-wise monthly percentage composition of food in the diet of *S. longiceps*.

Group	Jan	Feb	Mar	Apr	May	Aug	Sep	Oct	Nov	Dec
Diatoms	25.73	68.62	77.37	41.04	83.04	50.17	71.43	63.92	67.12	17.28
Blue green algae	-	-	-	-	-	2.81	-	-	-	-
Dinoflagellates	1.47	7.79	2.66	2.35	0.59	24.31	1.78	11.17	17.89	4.28
Zooplankton	67.21	22.68	6.34	55.12	6.45	15.37	24.66	24.06	14.87	76.26
Unrecognizable matter/ scales etc.	5.59	0.91	13.63	1.49	9.92	7.34	2.13	0.85	0.12	2.18

(No data in June and July due to fishing ban).

Table 3 — Monthly percentage frequency of occurrence of food items in diet of *S. longiceps*.

Group	Genera	Jan	Feb	Mar	Apr	May	Aug	Sep	Oct	Nov	Dec
Diatoms	<i>A. japonica</i>	42.86	39.29	37.04	11.11	42.86	12.50	-	-	-	14.29
	<i>Aulacodiscus</i> sp.	-	-	33.33	-	-	-	-	-	14.29	-
	<i>Bacillaria</i> sp.	80.95	57.14	37.04	22.22	46.43	25.00	14.29	-	85.71	31.43
	<i>Bacteriastrum</i> spp.	-	-	-	-	-	16.67	-	14.29	11.43	-
	<i>Biddulphia</i> spp.	14.29	32.14	11.11	-	71.43	29.17	71.43	28.57	100.00	-
	<i>C. pelagica</i>	-	39.29	-	-	-	-	-	-	-	-
	<i>Chaetoceros</i> spp.	9.52	28.57	25.93	18.52	-	50.00	28.57	46.43	45.71	28.57
	<i>Coscinodiscus</i> spp	100.00	85.71	81.48	66.67	89.29	75.00	100.00	85.71	100.00	100.00
	<i>Ditylum sol</i>	-	-	-	-	-	12.50	14.29	-	-	-
	<i>L. undulatum</i>	-	-	-	-	10.71	-	-	10.71	-	-
	<i>F. oceanica</i>	-	14.29	33.33	100.00	28.57	-	14.29	-	40.00	-
	<i>Nitzschia</i> spp.	76.19	32.14	11.11	37.04	39.29	100.00	90.48	100.00	100.00	11.43
	<i>Planktoniella sol</i>	28.57	-	-	-	-	12.50	47.62	-	-	-
	<i>Pleurosigma</i> spp.	100.00	67.86	59.26	37.04	85.71	-	47.62	57.14	100.00	57.14
	<i>Rhizosolenia</i> spp.	71.43	32.14	37.04	-	42.86	54.17	100.00	46.43	14.29	14.29
	<i>S. costatum</i>	14.29	-	37.04	33.33	100.00	-	-	-	74.29	-
	<i>T. nitzschioides</i>	-	46.43	29.63	59.26	57.14	91.67	33.33	89.29	100.00	-
	<i>Thalassiosira</i> spp.	14.29	-	33.33	-	14.29	-	-	28.57	31.43	-
<i>Thalassiothrix</i> spp.	9.52	17.86	-	-	-	16.67	-	-	14.29	-	
<i>Triceratium</i> spp.	-	46.43	-	11.11	17.86	-	42.86	32.14	-	-	
Blue green algae	<i>T. theibautii</i>	-	-	-	-	-	12.50	-	-	-	
Dinoflagellates	<i>Ceratium</i> spp.	-	28.57	-	-	-	75.00	14.29	53.57	100.00	17.14
	<i>Dinophysis</i> spp.	9.52	42.86	66.67	70.37	-	25.00	33.33	-	100.00	31.43
	<i>Glenodinium</i> spp.	-	39.29	11.11	22.22	-	-	14.29	14.29	-	14.29
	<i>Ornithocercus</i> sp.	19.05	28.57	-	33.33	-	-	28.57	-	97.14	11.43
	<i>Peridinium</i> spp.	28.57	46.43	22.22	37.04	42.86	45.83	14.29	14.29	100.00	14.29
	<i>P. micans</i>	23.81	32.14	25.93	-	-	41.67	-	-	60.00	28.57
Zoo-plankton	Copepoda	100.00	46.43	55.56	100.00	28.57	37.50	90.48	100.00	94.29	85.71
	Fish eggs	-	-	-	-	-	25.00	14.29	28.57	11.43	-
	Lucifer	-	10.71	-	29.63	14.29	-	-	-	14.29	42.86
	Nauplii	66.67	89.29	-	-	-	-	61.90	60.71	88.57	31.43
	Tintinnids	33.33	75.00	22.22	-	57.14	-	14.29	75.00	40.00	-
	Foraminifera	42.86	-	-	-	10.71	29.17	9.52	71.43	-	40.00
Bivalve larvae	-	-	-	-	-	-	14.29	-	-	28.57	
Unrecognizable matter/ scales etc.	19.05	14.29	11.11	33.33	14.29	12.50	19.05	32.14	17.14	14.29	

(No data in June and July due to fishing ban).

to 100% (January, September, November and December) and was considered to be “very common”. Copepods appeared in the food throughout the year with monthly percentage frequency ranging from 28.57% (May) to 100% (January, April and October).

In January, *Bacillaria* sp., *Coscinodiscus* spp., *Nitzschia* spp., *Pleurosigma* spp. and copepods appeared in 80.95%, 100%, 76.19%, 100% and 100% of the stomachs studied, respectively and were considered as “very common”. *Rhizosolenia* spp. and nauplii occurred in 71.43% and 66.67% of stomachs and were considered as “common”. *Asterionella japonica* and *Globigerina* sp. each were encountered in 42.86% of stomachs studied and were considered as “frequent” members. The remaining forms which

appeared in less than 25% of the stomachs studied were treated as “rare” food items. In February, only *Coscinodiscus* spp. and nauplii were considered as “very common” food appearing in 85.71% and 89.29% of stomachs. *Bacillaria* sp., *Pleurosigma* spp. and tintinnids appeared in 57.14%, 67.86% and 75% of stomachs studied and were considered as “common”. In March, *Coscinodiscus* spp. appeared in 81.48% of stomachs, *Pleurosigma* spp. in 59.26%, *Dinophysis* spp. in 66.67% and copepod in 55.56% of the stomachs studied. The rest of the food items were considered as “frequent” or “rare” based on their percentage occurrence. The percentage frequency of *F. oceanica* and copepods in April was recorded as 100% and that of *Coscinodiscus* spp., *T. nitzschioides*

and *Dinophysis* spp. as 66.67%, 59.26% and 70.37%, respectively and were considered as “common”. In the month of May, *S. costatum* and *Coscinodiscus* spp. were encountered in 100% and 89.29% of stomachs and were considered as “very common”. The percentage frequency of *Nitzschia* spp. and *Thalassionema* spp. was more than 75% in August, while in September, *Coscinodiscus* spp. (100%), *Nitzschia* spp. (90.48%), *Rhizosolenia* spp. (100%) and copepods (90.48%) were considered as “very common” food items.

In October, *Coscinodiscus* spp., *T. nitzschioides*, *Nitzschia* spp. and copepods appeared in 85.71%,

89.29%, 100% and 100%, respectively. The tintinnids and foraminifera were encountered in 75% and 71.43% of stomachs studied and were considered as “common”. The percentage frequency of the occurrence of most of the food items was very high in November. *Biddulphia* spp., *Coscinodiscus* spp., *Nitzschia* spp., *Pleurosigma* spp., *T. nitzschioides*, *Ceratium* spp., *Dinophysis* spp. and *Peridinium* spp. appeared in the food in all the stomachs studied, while *Bacillaria* sp., *S. costatum*, *Ornithocercus* sp., copepods and nauplii appeared in 85.71%, 74.29%, 97.14%, 94.29% and 88.57% of the stomachs, respectively.

Group	Genera	Jan	Feb	Mar	Apr	May	Aug	Sep	Oct	Nov	Dec
Diatoms	<i>A. japonica</i>										
	<i>Aulacodiscus</i> sp.										
	<i>Bacillaria</i> sp.										
	<i>Bacteriastrium</i> spp.										
	<i>Biddulphia</i> spp.										
	<i>C. pelagica</i>										
	<i>Chaetoceros</i> spp.										
	<i>Coscinodiscus</i> spp										
	<i>Ditylum</i> sol										
	<i>L. undulatum</i>										
	<i>F. oceanica</i>										
	<i>Nitzschia</i> spp.										
	<i>Planktoniella</i> sol										
	<i>Pleurosigma</i> spp.										
	<i>Rhizosolenia</i> spp.										
	<i>S. costatum</i>										
	<i>T. nitzschioides</i>										
	<i>Thalassiosira</i> spp.										
<i>Thalassiothrix</i> spp.											
<i>Triceratium</i> spp.											
Blue green algae	<i>T. theibautii</i>										
Dinoflagellates	<i>Ceratium</i> spp.										
	<i>Dinophysis</i> spp.										
	<i>Glenodinium</i> spp.										
	<i>Ornithocercus</i> sp.										
	<i>Peridinium</i> spp.										
	<i>P. micans</i>										
Zooplankton	Copepoda										
	Fish eggs										
	Lucifer										
	Nauplii										
	Tintinnids										
	Foraminifera										
	Bivalve larvae										
Unrecognizable matter/ scales etc.											

(No data in June and July due to fishing ban)

LEGEND						
Rare		Frequent		Common		Very common

Fig. 2 – Monthly percentage frequency of occurrence of food items in diet of *S. longiceps*.

Index of preponderance

The index of preponderance of different food items consumed by *S. longiceps* is presented as food item-wise (Table 4) as well as group-wise (Table 5). It shows that diatoms, blue-green algae, dinoflagellates, zooplankton and unrecognizable matter are the food items consumed by the fish.

Diatoms formed the most dominant group (Rank 1; 80.814%) in the diet. The most dominant diatoms were *Coscinodiscus* spp. (25.64%) followed by *Nitzschia* spp. (6.96%), *Pleurosigma* spp. (6.22%), *Rhizosolenia* spp. (4.87%), *S. costatum* (3.43%), etc. (Table 4). Zooplankton formed the second most important group (15.95%), which included copepods, fish eggs, Lucifer, nauplii, tintinnids, foraminifera (*Globigerina* spp.), and bivalve larvae. The copepods identified in the diet

included *Cyclops* spp., *Calanus* spp., *Pseudocalanus* spp., *Paracalanus* spp., *Microsetella* spp., and *Eurytemora* spp. The copepods formed the most dominant food item (Rank 1; 36.73%) among all the food items encountered in the gut contents. The other zooplankters encountered were: Nauplii (1.96%), tintinnids (0.41%), Foraminifera (0.34%), fish eggs (0.26%), lucifer (0.08%), and bivalve larvae (0.01%). Dinoflagellates belonging to six genera were identified in the diet of *S. longiceps*, and as a group ranked third having an index of preponderance of 3.004%. The most dominant among the dinoflagellates was *Ceratium* spp. (2.02%) followed by *Dinophysis* spp. (0.90%), *Peridinium* spp. (0.59%), *Porocentrum micans* (0.28%), *Ornithocercus* spp. (0.14%), and *Glenodinium* spp. (0.04%).

Table 4 — Index of Preponderance of food items of *S. longiceps*.

Group	Food item	Pi (Avg. % of points)	Oi (Avg. % of occurrence)	Pi * Oi	IP	Rank
Diatoms	<i>A. japonica</i>	0.356288	2.480739	0.883857	0.153097	23
	<i>Aulacodiscus</i> sp.	0.117126	0.581042	0.068055	0.011788	30
	<i>Bacillaria</i> sp.	1.634051	4.417913	7.219096	1.250454	12
	<i>Bacteriastrium</i> spp.	0.031533	0.426267	0.013442	0.002328	34
	<i>Biddulphia</i> spp.	1.097893	3.583953	3.934797	0.681565	16
	<i>C. pelagica</i>	1.781443	0.395683	0.704888	0.122097	25
	<i>Chaetoceros</i> spp.	0.472833	3.187395	1.507105	0.261053	21
	<i>Coscinodiscus</i> spp	14.33928	10.32290	148.023	25.63977	2
	<i>Ditylum sol</i>	0.088878	0.309311	0.027491	0.004762	33
	<i>L. undulatum</i>	0.039181	0.239882	0.009399	0.001628	35
	<i>F. oceanica</i>	4.319431	2.778922	12.00336	2.079160	7
	<i>Nitzschia</i> spp.	6.294309	6.382952	40.17627	6.959123	3
	<i>Planktoniella sol</i>	0.255777	0.982244	0.251235	0.043518	28
	<i>Pleurosigma</i> spp.	5.216570	6.880863	35.89451	6.217458	4
	<i>Rhizosolenia</i> spp.	5.950877	4.724228	28.1133	4.869638	5
	<i>S. costatum</i>	6.898394	2.868923	19.79096	3.428086	6
	<i>T. nitzschoides</i>	1.361401	5.473561	7.451710	1.290746	11
	<i>Thalassiosira</i> spp.	3.416269	1.313478	4.487195	0.777248	14
<i>Thalassiothrix</i> spp.	0.241419	0.585364	0.141318	0.024478	29	
<i>Triceratium</i> spp.	2.659186	1.624864	4.320815	0.748429	15	
Blue green algae	<i>T. theibautii</i>	0.280656	0.156250	0.043853	0.007596	32
Dino-flagellates	<i>Ceratium</i> spp.	4.102035	2.841007	11.65391	2.018630	8
	<i>Dinophysis</i> spp.	1.207884	4.311822	5.208179	0.902134	13
	<i>Glenodinium</i> spp.	0.183832	1.395366	0.256513	0.044432	27
	<i>Ornithocercus</i> sp.	0.380204	2.076142	0.789357	0.136728	24
	<i>Peridinium</i> spp.	0.869634	3.893885	3.386253	0.586549	17
	<i>P. micans</i>	0.686660	2.337159	1.604835	0.277981	20
Zooplankton	Copepoda	24.75204	8.568074	212.0773	36.73493	1
	Fish eggs	1.789115	0.827899	1.481207	0.256567	22
	Lucifer	0.309264	1.479965	0.457699	0.079280	26
	Nauplii	2.839121	3.992219	11.33439	1.963284	9
	Tintinnids	0.709699	3.320195	2.356338	0.408153	18
	Foraminifera	0.798686	2.442057	1.950438	0.337845	19
	Bivalve larvae	0.103564	0.616024	0.063798	0.011051	31
Unrecognizable matter/ scales etc.	4.415459	2.181449	9.632097	1.668421	10	

Table 5 — Group-wise Index of Preponderance of food items in the diet of *S. longiceps*.

Group	Pi (Avg. % of points)	Oi (Avg. % of occurrence)	Pi * Oi	IP	Rank
Diatoms	56.57	59.56	3369.46	80.814	1
Blue green algae	0.28	0.16	0.04	0.001	5
Dinoflagellates	7.43	16.86	125.24	3.004	3
Zooplankton	31.30	21.25	665.05	15.950	2
Unrecognized matter/ scales etc.	4.42	2.18	9.63	0.231	4

Table 6 — Month-wise index of preponderance of different food items in *S. longiceps*.

Groups	Food items	Jan	Feb	Mar	Apr	May	Aug	Sep	Oct	Nov	Dec
Diatoms	<i>A. japonica</i>	0.09	0.22	0.83	0.11	0.67	0.02	-	-	-	0.01
	<i>Aulacodiscus</i> sp.	-	-	0.99	-	-	-	-	-	0.01	-
	<i>Bacillaria</i> sp.	2.45	0.36	7.45	0.80	0.40	0.08	0.02	-	0.69	0.34
	<i>Bacteriastrium</i> spp.	-	-	-	-	-	0.03	-	0.03	-	-
	<i>Biddulphia</i> spp.	0.01	1.78	0.04	-	1.77	0.09	2.16	0.17	2.84	-
	<i>C. pelagica</i>	-	13.40	-	-	-	-	-	-	-	-
	<i>Chaetoceros</i> spp.	0.01	0.07	0.10	0.19	-	0.97	0.17	0.25	0.04	0.54
	<i>Coscinodiscus</i> spp	6.19	10.55	18.21	7.56	12.86	35.15	21.54	45.53	7.30	11.53
	<i>Ditylum sol</i>	-	-	-	-	-	0.14	0.05	-	-	-
	<i>L. undulatum</i>	-	-	-	-	0.04	-	-	0.01	-	-
	<i>F. oceanica</i>	-	0.44	19.86	17.78	0.50	-	0.10	-	1.29	-
	<i>Nitzschia</i> spp.	1.10	-	0.27	0.14	0.11	8.84	3.81	11.48	44.56	0.03
	<i>Planktoniella sol</i>	0.10	-	-	-	-	0.10	1.00	-	-	-
	<i>Pleurosigma</i> spp.	12.04	19.77	2.76	0.24	7.45	-	0.60	1.89	6.79	4.12
	<i>Rhizosolenia</i> spp.	0.89	0.61	1.03	-	0.24	12.09	48.21	1.09	0.03	0.12
	<i>S. costatum</i>	0.06	-	3.03	3.09	70.79	-	-	-	1.07	-
<i>T. nitzschioides</i>	-	0.59	1.27	1.91	0.39	3.56	0.11	3.54	2.76	-	
<i>Thalassiosira</i> spp.	0.02	-	27.00	-	0.09	-	-	1.29	0.10	-	
<i>Thalassiothrix</i> spp.	0.01	0.06	-	-	-	0.58	-	-	0.03	-	
<i>Triceratium</i> spp.	-	19.61	-	0.14	0.17	-	0.90	0.39	-	-	
Blue green algae	<i>T. theibautii</i>	-	-	-	-	-	0.63	-	-	-	
Dinofla-gellates	<i>Ceratium</i> spp.	-	1.71	-	-	-	24.21	0.10	7.46	8.57	0.06
	<i>Dinophysis</i> spp.	0.01	1.63	2.98	1.09	-	0.17	0.17	-	5.09	0.59
	<i>Glenodinium</i> spp.	-	0.37	0.04	0.11	-	-	0.02	0.02	-	0.10
	<i>Ornithocercus</i> sp.	0.02	0.27	-	0.13	-	-	0.14	-	1.05	0.22
	<i>Peridinium</i> spp.	0.17	1.21	0.38	0.14	0.32	1.07	0.04	0.03	3.50	0.05
	<i>P. micans</i>	0.15	0.20	0.19	-	-	3.49	-	-	0.36	0.15
Zoo-plankton	Copepoda	58.99	12.10	9.31	65.69	1.77	0.58	12.94	18.63	12.20	77.99
	Fish eggs	-	-	-	-	-	6.36	0.38	0.41	0.04	-
	Lucifer	-	0.06	-	0.27	0.07	-	-	-	0.04	0.81
	Nauplii	3.53	13.32	-	-	-	-	6.93	1.79	1.44	0.79
	Tintinnids	0.14	1.42	0.12	-	0.53	-	0.04	3.92	0.18	-
	Foraminifera	0.65	-	-	-	0.05	0.19	0.03	1.72	-	1.87
	Bivalve larvae	-	-	-	-	-	-	0.06	-	-	0.26
Unrecognizable matter/ scales etc.	13.37	0.25	4.14	0.61	1.78	1.65	0.48	0.35	0.02	0.42	

(No data in June and July due to fishing ban)

Table 7 : Monthwise Index of preponderance for different groups in the diet of *S. longiceps*.

Groups	Jan	Feb	Mar	Apr	May	Aug	Sep	Oct	Nov	Dec
Diatoms	22.97	67.46	82.84	31.96	95.48	61.65	78.67	65.67	67.51	16.69
Blue green algae	-	-	-	-	-	0.63	-	-	-	-
Dino-flagellates	0.35	5.39	3.59	1.47	0.32	28.94	0.47	7.51	18.57	1.17
Zooplankton	63.31	26.90	9.43	65.96	2.42	7.13	20.38	26.47	13.90	81.72
Unrecognized matter/ scales etc.	13.37	0.25	4.14	0.61	1.78	1.65	0.48	0.35	0.02	0.42

(No data in June and July due to fishing ban)

Unrecognizable matter ranked fourth (1.67%) as a group. This group included mud, fish scales and detritus. Blue-green algae represented by a single species, *T. theibautii* ranked fifth (0.007%).

Monthly index of preponderance of different food items as well as different groups of food items (Tables 4 & 5) indicate that diatoms were dominant in all the months except in January (22.97%), April (31.96%) and December (16.69%). Among the diatoms, *Coscinodiscus* spp. formed the most important component of the diet in October (45.53%) and August (35.15%), *Nitzschia* spp. ranked first among the diatoms in November (44.56%), *S. costatum* in May (70.79%), and *Rhizosolenia* spp. in September (48.21%). Blue-green algae *T. theibautii* was observed only in August (0.63%).

Zooplankton formed the most important component of the diet in January (63.31%), April (65.96%) and December (81.73%). Among this group, copepods dominated in all the months except in February (12.10%) and August (0.58%). Nauplii were the dominant zooplankters in February (13.32%), while fish eggs ranked first among the zooplankters in August (6.36%).

Dinoflagellates ranked second in August (28.94%) and November (18.57%) while in the other months their index of preponderance was low ranging from 0.32% in May to 7.51% in October. Unrecognizable matter comprising mud, fish scales and detritus ranged from 0.02% (November) to 13.37% (January). Blue-green algae *T. theibautii* was observed only in August (0.63%).

Discussion

S. longiceps is found to be a planktivorous fish, feeding mainly on diatoms (*Asterionella japonica*, *Aulacodiscus* sp., *Bacillaria* sp., *Bacteriastrum* sp., *Biddulphia mobiliensis*, *B. sinensis*, *B. favus*, *Cerataulina pelagica*, *Chaetoceros* spp., *Coscinodiscus excentricus*, *C. lineatus*, *C. radiatus*, *Ditylum sol*, *Lithodesmium undulatum*, *Fragilaria oceanica*, *Nitzschia closterium*, *N. seriata*, *Planktoniella sol*, *Pleurosigma* spp., *Rhizosolenia* spp., *Skeletonema costatum*, *Thalassionema nitzschioides*, *Thalassiosira* spp., *Thalassiothrix* sp., *Triceratium* sp., and *Triceratium malleus*); dinoflagellates (*Ceratium longipes*, *C. furca*, *C. fusus*, *C. tripos*, *C. macroceros*, *Dinophysis acuta*, *D. tripos*, *D. caudata*, *D. miles*, *Glenodinium* spp., *Ornithocercus* sp., *Peridinium* spp., and *Porocentrum micans*); zooplankton (copepods, fish eggs, Lucifer,

nauplii, Tintinnids, Foraminifera, and bivalve larvae); blue green algae (*Trichodesmium theibautii*), and unrecognizable matter (mud, fish scales, and detritus).

The group-wise index of preponderance indicates diatoms to be the dominant group followed by zooplankton and dinoflagellates. Month-wise index of preponderance (Tables 6 & 7) indicates diatoms to be the dominant food in all the months except January and December. Most clupeid fishes are known to change their feeding habits seasonally, with low or complete cessation of feeding during spawning season and intense feeding after spawning. Scott and Crossman⁷ reported that feeding increased after spawning in the clupeid American shad, *Alosa spidissima*. Various authors have also reported resumption of feeding heavily after spawning in the herrings^{8,9}.

The earlier works have also observed diatoms, dinoflagellates and copepods mainly forming the food of the oil sardine. In the present study also, these three groups have been found to comprise the bulk of the food of the species. Diatoms formed an important food item, as has been observed in Trivandrum¹⁰, Calicut^{11,12,13,14}, and Mangalore¹⁵. However, diatoms did not dominate in all the months as has been noticed by other workers^{3,16}. Especially in the months of December and January, diatoms were recorded in less quantity in the stomachs of this species. *Fragilaria oceanica* has been reported to be the indicator species of oil sardine^{3,15,17}. However, in the present study, the diatoms were observed in some months only and that too in smaller quantities, not to the extent of calling it 'indicator' species. Several authors working in various locations in India have also reported absence or negligible amounts of *F. oceanica* in the diet of *S. longiceps*^{16,18,19,20}.

Copepods contributed plentifully to the diet of the oil sardine and were equally important and dominating in some months. Similar observations have been reported by Noble¹⁶ for oil sardine from Karwar. Dinoflagellates (like *Ceratium* spp., *Peridinium* spp. and *Porocentrum micans*), fish eggs, tintinnids and bivalve larvae appeared in the diet generally in the post-monsoon months. Among dinoflagellates, *Ceratium* spp. was the most abundant and dominant in the post-monsoon period. Noble¹⁶ has also reported abundance of dinoflagellates, tintinnids and larval forms in the diet of oil sardine in the post-monsoon months. Devanesan²¹ pointed out

that the oil sardines feed normally and regularly on the fish eggs occurring in the plankton of Kozhikode coast. On the other hand, John and Menon¹⁰ never observed any fish eggs in the stomach contents of the oil sardine of the Trivandrum coast and classified oil sardines as essentially phytoplankton feeders. In the present investigation, fish eggs were encountered in the food from August to November, the period being the spawning season of most of the fishes on the west coast of India.

Unrecognizable matter comprising mud, fish scales and detritus were observed in the stomach contents throughout the year. Several authors have reported that unrecognizable detritus form a bulk of the stomach contents^{11,12,22}. It has been reported that from the point of view of meeting the nutritional requirements of the fish, detritus is as important an item as the planktonic forms³.

It may not be out of place to discuss here the selective feeding behaviour of *S. longiceps*³. Among the numerous planktonic organisms, preference was shown for some diatoms, dinoflagellates and copepods, like *Coscinodiscus* spp., *Nitzschia* spp., *Pleurosigma* spp., *Rhizosolenia* spp., *Biddulphia* spp., *Thalassionema* spp., *Ceratium* spp., *Dinophysis* spp., copepods, and nauplii which appeared in the food almost throughout the year in fair quantities. Subrahmanyam and Sarma²³ recorded 226 species of Bacillariophyceae, 120 species of Dinophyceae and 7 species of Cyanophyceae from the waters off the west coast of India; but out of these, members of only 27 genera were found in the diet of *S. longiceps*, in the present study. The total absence of numerous phytoplanktonic and zooplanktonic forms from the diet of oil sardine indicates a certain amount of selectivity in the food consumed by the fish.

Acknowledgement

The authors are grateful to Director, Central Institute of Fisheries Education (CIFE), Mumbai and to Indian Council of Agricultural Research (ICAR), New Delhi, for providing necessary facilities for carrying out this research work.

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