Indian J. Fish., 69(2): 56-65, 2022
DOI: 10.21077/ijf.2022.69.2.108213-07

Food and feeding habits of *Sardinella longiceps* Valenciennes, 1847 caught along Veraval coast of Gujarat

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ABSTRACT

This study is based on the examination of gut contents of 351 specimens of *Sardinella longiceps* Valenciennes, 1847 landed at Veraval Harbour, Gujarat. Feeding intensity of *S. longiceps* was reduced during spawning season and gradually increased during post-spawning period. The fish was found to be a planktivorous species consuming diatoms, dinoflagellates, zooplankton and unrecognisable matter. Diatoms were the most dominant group followed by zooplankton and dinoflagellates. Unrecognisable matter comprising mud, detritus and sand particles were observed in the stomach of *S. longiceps* throughout the study period. Index of preponderance values showed that the diatoms (57.17%) and zooplankton (36.51%) were the major components of the diet.

Keywords: Arabian Sea, Diet analysis, Indian oilsardine, Trophodynamics

Introduction

The Indian oilsardine *Sardinella longiceps* Valenciennes, 1847 belonging to the family Clupeidae has a wide distribution along the Indian coast extending from Gujarat on the west coast to West Bengal on the east coast including the Andaman and Nicobar Islands. It has been also reported that occasionally the species occur in estuaries too (CMFRI, 2005). The Indian oilsardine is considered the most important single species in India's marine fisheries contributing 17-20% of the country's marine landings (Rohit *et al.,* 2018). Recently the species which used to be at the first position few years ago moved to the 10th position with only 0.083 million t being landed in 2020 in India (3.05% of national total) (CMFRI, 2020). Among the maritime states of India, Gujarat is a leading state contributing to marine fish landings. Clupeids (41,426 t) constituted 20% of pelagic resources and 7.8% of total landings in Gujarat (CMFRI, 2020). *S. longiceps* contributed less than 0.01 lakh t in 2019-20 in Gujarat (DOF, 2020).

S. longiceps is a pelagic species which is confined to a depth ranging from 20 to 200 m which shows rapid growth and early maturity (Longhurst and Wooster, 1990). Oilsardine attains sexual maturity at around one-year of age or at a size of approximately 15 cm length (Hornell and Nayudu, 1924; Balan, 1964; Antony, 1969). Oilsardine survives up to a maximum of 2.5 years at which they likely attain a maximum length of 230 mm (Balan, 1964). They play a very important role in marine pelagic ecosystem. The most preferred food of oilsardine is plankton and it forms a major food source for large predators as a prey (Nair *et al.*, 2016; Shah *et al.*, 2019). Though studies on *S. longiceps* diet is available from other parts of India, only limited information is available from Gujarat. Hence this study was conducted to analyse the diet of *S. longiceps* from Veraval, Gujarat. The results of this study can be used as inputs for ecosystem-based models, trophic models and for climate change impact studies in the region.

Materials and methods

The present study was conducted along the Veraval fishing ground (20°54'912''N; 70°21'355''E), which is situated in the Gir-Somnath District along the western coast of Gujarat State. A total of 351 specimens of *S. longiceps* was collected at fortnightly intervals from September 2019 to March 2020.

After recording total length and weight, the fishes were dissected to examine the stomach conditions. The feeding intensity was assessed based on the fullness of the stomach and the volume of food contained in it by eye estimation and classified as full, ¾ full, ½ full and empty.

After assessing the feeding intensity, the stomachs were cut open and food items were examined. As oilsardine is a plankton feeder, the stomach content was made up to a known volume (10 ml); 1 ml from this mixture was taken on a slide and various food items were identified and counted under microscope (Kagwade, 1964). The point method was followed in this study, where each food item was allotted a certain number of points based on

quantity and all the points gained by different food items were summed and expressed to percentage composition of the guts content (Hynes, 1950). The occurrence method was also followed where the number of food items was expressed as a percentage based on the presence or absence of specific food items in stomach samples. The occurrence and points of items in every stomach were noted for calculating the index of preponderance (IP). Index of preponderance of various food items in the gut was calculated by the method given by Natarajan and Jhingaran (1961) using the formula:

$$IP = \frac{Vi*Oi}{\sum Vi*Oi} \times 100$$

where, V_i = Percentage composition of i^{th} food item and O_i = Frequency of occurrence of i^{th} food item.

Additionally a cluster analysis was carried out, which is a multivariate analysis technique in which the entities were sequentially linked together based on their similarity or dissimilarity producing a two-dimensional hierarchical structure *i.e.,* dendogram from which a similarity index is calculated among the months to determine the similarity of the diet (Hammer *et al*., 2001).

Results

Feeding intensity

During the present investigation, a total of 351 stomachs of *S. longiceps* ranging from 145 to 236 mm total length (TL) were examined. The feeding intensity of *S. longiceps* was low during the spawning season (September to December). The analysis of stomach contents showed that 35.61, 18.51, 19.09 and 26.78% of individuals had empty, half full, three fourth full and full stomachs respectively. Empty stomach was noted in all the months except February and March and empty stomachs dominated during September-November. More than 50% fishes had full stomachs during January-March (Table 1).

The percentage of full stomachs was the highest (60%) in February and absent in September-November. Percentage of stomach with three-fourth contents was highest (28%) in March and the lowest (10%) in October. The stomach with half-full contents was highest (29.41%) in September and lowest (12%) in December. Empty stomach was highest (70%) in October and absent in February-March period.

The overall feeding intensity of males was higher than the female *S. longiceps*. The females had higher (approx. 41%) empty stomachs than males. The decline in feeding intensity was seen more in females than males during the peak spawning period of September to December and the feeding intensity of both males and females increased during post-spawning period (Table 2 and 3). The results showed that the feeding intensity was not related to the fish size (Table 4).

Gut content

The gut contents of *S. longiceps* were analysed quantitatively and qualitatively. The main food items could

Table 1. Monthly variations in feeding intensity of *S. longiceps*

Month	Total no. of fishes	Full	¾ Full	½ Full	Empty
September 2019	51	0	11.77	29.41	58.82
October 2019	50	0	10	20	70
November 2019	50	0	14	18	68
December 2019	50	26	20	12	42
January 2020	50	50	24	16	10
February 2020	50	60	26	14	0
March 2020	50	52	28	20	0
Annual	351	26.78	19.09	18.51	35.61

Table 2. Monthly variations in feeding intensity of male *S. longiceps*

Month	Total no. of fishes	Full	¾ Full	½ Full	Empty
September 2019	24	0	16.67	33.33	50
October 2019	17	0	29.41	41.18	29.41
November 2019	21	0	33.33	19.05	47.62
December2019	18	16.67	16.67	11.11	55.55
January 2020	19	47.37	5.26	31.58	15.79
February 2020	26	38.46	34.62	26.92	0
March 2020	18	66.67	11.11	22.22	0
Annual	143	23.78	21.68	26.57	27.97

Table 3. Monthly variations in feeding intensity of female *S. longiceps*

Month	Total no. of fishes	Full	¾ Full	½ Full	Empty
September 2019	27	0	7.41	25.92	66.67
October 2019	33	0	0	9.09	90.91
November 2019	29	0	0	17.24	82.76
December 2019	32	31.25	21.88	12.5	34.37
January 2020	31	51.61	35.49	6.45	6.45
February 2020	24	83.33	16.67	0	0
March 2020	32	43.75	37.5	18.75	0
Annual	208	28.85	17.30	12.98	40.87

Table 4. Variations in the feeding intensity in different length class of *S. longiceps*

Class interval	Full	¾ Full	½ Full	Empty
141-150	-	100	-	-
151-160	33.33	44.45	-	22.22
161-170	44.45	22.22	11.11	22.22
171-180	20	26.67	20	33.33
181-190	21.88	21.87	25	31.25
191-200	23.68	17.11	18.42	40.79
201-210	24.49	15.65	22.45	37.41
211-220	28.85	23.08	15.38	32.69
221-230	75	12.5	-	12.5
231-240	100	-	-	-

be grouped into diatoms, dinoflagellates, zooplankton and unrecognisable matter. The monthly composition of food items observed in the diet of *S. longiceps* based on the points method is presented based on food items (Table 5) and group-wise (Fig. 1).

The most dominant group observed was diatoms consisting of 18 species/genera which included *Asterionella japonica*, *Aulacodiscus* sp., *Bacillaria* sp., *Bacteriastrum* sp., *Biddulphia* sp., *Cerataulina pelagica*, *Chaetoceros* sp., *Coscinodiscus* sp., *Fragilaria oceanica*, *Nitzchia* sp., *Planktoniella sol*, *Pleurosigma* sp., *Rhizosolenia* sp., *Skeletonema costatum*, *Thalassionema nitzschioides*, *Thalassiosira* sp., *Thalassiothrix* sp. and *Triceratium* sp. The bulk of food comprised of diatoms in all the months except December (22.38%) and January (28.55%). In other months, the percentage composition of diatoms ranged from 64.53% in February to 74.57% in March. *Rhizosolenia* sp. (39.28%) was the most dominant food item in September, *Coscinodiscus* sp. (40.42%) in October, *Nitzschia* sp. (37.22%) in November, *Triceratium* sp. (19.52%) in February and *Thalassiosira* sp. (29.65%) in March. The most dominant diatoms were *Rhizosolenia* sp., *Pleurosigma* sp., *Nitzschia* sp. and *Coscinodiscus* sp. whereas *Thalassiothrix* sp., *Planktoniella sol*, *Fragilaria oceanica*, *Bacteriastrum* sp. and *Aulacodiscus* sp. were the least dominant diatoms.

The second most important group was zooplankton which included *Acetes* sp., Amphipods, Copepods, Foraminifera, Lucifer and Tintinninds. The highest percentage composition of zooplankton was in the months of December (71.62%) and January (68.04%). The most dominant zooplankton throughout the study period (except in March which was 5.46%) was Copepod forming the bulk of stomach contents in January (59.24%) and December (64.71%). *Acetes* sp. was observed throughout the study period and was dominant among zooplankton in March (6.59%). Amphipod and Tintinnids were encountered in small numbers throughout the study period. Foraminifera were observed in small numbers throughout the study period except in February and March, when it was absent. Lucifer was observed in November, February and March in very few numbers.

Dinoflagellates consisted of *Ceratium* sp., *Dinophysis* sp., *Glenodinium* sp., *Surirella* sp. and *Peridinium* sp. *Ceratium* sp. was the most dominant dinoflagellate observed throughout the study period contributing 7.95% in October and 7.46% in November. *Surirella* sp. and *Peridinium* sp. were encountered in small numbers throughout the study period.

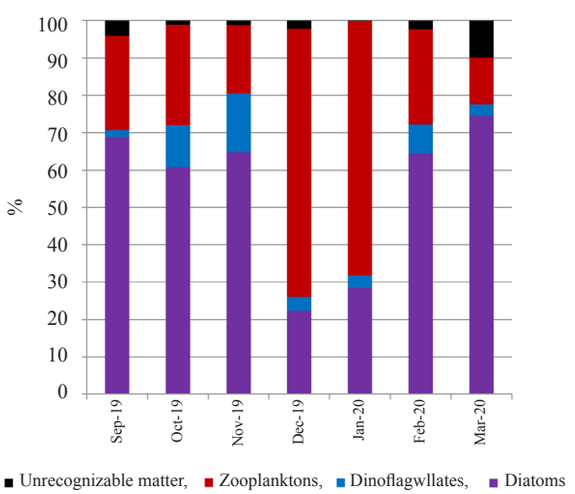

Fig. 1. Monthly percentage composition of food items in *S. longiceps* diet

Table 5. Monthly percentage composition of food items in *S. longiceps* diet

Group	Food item	September 2019	October 2019	November 2019	December 2019	January 2020	February 2020	March 2020
Diatoms	*Asterionella japonica*	-	-	0.07	0.14	0.22	0.58	0.97
	Aulacodiscus sp.	-	-	-	-	-	0.09	1.05
	Bacillaria sp.	0.14	0.24	1.3	1.54	3.22	1.08	6.88
	Bacteriastrum sp.	-	-	0.06	-	-	-	-
	Biddulphia sp.	2.32	1.57	2.22	-	0.07	2.64	0.12
	Cerataulina pelagica	-	-	-	-	0.09	14.35	-
	Chaetoceros sp.	0.45	0.36	0.1	0.74	0.2	0.14	0.16
	Coscinodiscus sp.	18.3	40.42	10.21	9.88	6.62	6.75	11.52
	Fragilaria oceanica	-	-	0.06	-	-	0.07	-
	Nitzschia sp.	3.34	9.62	37.22	3.38	1.12	0.07	1.98
	Planktoniella sol	1.48	0.09	-	-	0.32	-	-
	Pleurosigma sp.	1.48	2.61	6.78	5.32	11.67	16.96	6.72
	Rhizosolenia sp.	39.28	6.83	2.72	1.38	2.48	1.64	10.95
	Skeletonema costatum	-	-	1.04	-	-	-	3
	Thalassionema nitzschioides	0.32	2.08	2.5	-	-	0.49	1.57
	Thalassiosira sp.	-	-	0.3	-	0.1	-	29.65
	Thalassiothrix sp.	-	-	0.2	-	0.2	0.15	-
	Triceratium sp.	1.72	0.76	-	-	2.24	19.52	-
	Total	68.83	64.58	64.78	22.38	28.55	64.53	74.57
Dino-flagellates	*Ceratium* sp.	0.62	7.95	7.46	0.1	-	2.98	1.2
	Dinophysis sp.	0.38	-	3.85	1.32	1.54	1.79	1.12
	Glenodinium sp.	0.21	-	-	0.52	-	0.19	-
	Surirella sp.	0.45	0.26	1.62	1.46	0.48	0.44	0.1
	Peridinium sp.	0.21	0.3	2.79	0.32	1.24	2.34	0.67
	Total	1.87	8.51	15.72	3.72	3.26	7.74	3.09
Zoo-plankton	*Acetes* sp.	8.12	4.88	5.26	4.82	5.64	8.64	6.59
	Amphipod	4.94	1.81	0.98	0.87	2.54	3.54	-
	Copepoda	11.88	13.9	10.22	64.71	59.24	12.46	5.46
	Foraminifera	0.12	2.02	1.28	1.14	0.2	-	-
	Lucifer	-	-	0.1	-	-	0.2	0.1
	Tintinnids	0.21	3.14	0.42	0.08	0.42	0.69	0.32
	Total	25.27	25.75	18.26	71.62	68.04	25.53	12.47
Unrecognisable matter		4.03	1.16	1.24	2.28	0.15	2.2	9.87

Unrecognisable matter consisted of mud and detritus which was observed throughout the study period in varying quantities with the highest amount in March (9.87%).

Frequency of occurrence of food items

The month-wise percentage frequency of occurrence of food items found in *S. longiceps* stomach is presented in Table 6. The food items were grouped based on occurrence into absent (Nil or 0%), rare (0-25%), frequent (26-50%), common (51-75%) and very common (76-100%).

Diatoms and zooplankton were the two major food components consumed by *S. longiceps*. *Coscinodiscus* sp. was considered to be very common as it was observed in high amounts throughout the study period. Copepod was considered "very common" throughout the study period except in March, when it was "common". *Acetes* sp. was "very common" throughout the study period except in November and December when it was "common". *Fragilaria oceanica* was rarely found and was seen only in November and February.

In September, *Biddulphia* sp., *Coscinodiscus* sp., *Nitzschia* sp., *Rhizosolenia* sp., *Acetes* sp., Amphipod and Copepods were "very common" food items encountered in the diet of *S. longiceps*. *Chaetoceros* sp., *Planktoniella sol*, *Pleurosigma* sp. and *Thalassionema nitzschioides* were considered as "frequent". The remaining food items that appeared in less than 25% of stomachs were considered "rare" food items. In October, *Coscinodiscus* sp.,

Table 6. Monthly percentage frequency of occurrence of food items in *S. longiceps*

Group	Food item	September 2019	October 2019	November 2019	December 2019	January 2020	February 2020	March 2020
Diatoms	*Asterionella japonica*							
	Aulacodiscus sp.							
	Bacillaria sp.							
	Bacteriastrum sp.							
	Biddulphia sp.							
	Cerataulina pelagica							
	Chaetoceros sp.							
	Coscinodiscus sp.							
	Fragilaria oceanica							
	Nitzschia sp.							
	Planktoniella sol							
	Pleurosigma sp.							
	Rhizosolenia sp.							
	Skeletonema costatum							
	Thalassionema nitzschioides							
	Thalassiosira sp.							
	Thalassiothrix sp.							
	Triceratium sp.							
Dino-flagellates	*Ceratium* sp.							
	Dinophysis sp.							
	Glenodinium sp.							
	Surirella sp.							
	Peridinium sp.							
Zoo-plankton	*Acetes* sp.							
	Amphipod							
	Copepoda							
	Foraminifera							
	Lucifer							
	Tintinnids							
Unrecognisable matter								

Legend

Very common | Common | Frequent | Rare | Absent

Nitzschia sp., *Acetes* sp. and Copepods were "very common". *Bacillaria* sp., *Biddulphia* sp. and *Chaetoceros* sp. were "frequent" food items. *Planktoniella sol*, *Triceratium* sp., *Surirella* sp. and *Peridinium* sp. were "rare". In November, *Coscinodiscus* sp., *Nitzschia* sp., *Pleurosigma* sp., *Thalassionema nitzschioides, Ceratium* sp., *Dinophysis* sp., *Peridinium* sp. and Copepods were "very common". *Bacillaria* sp., *Biddulphia* sp. and *Acetes* sp. were "common" food items. *F. oceanica* was encountered in the diet of *S. longiceps* which was recorded as a "rare" food item. In December, *Bacillaria* sp., *Coscinodiscus* sp. and Copepods were "very common". *Nitzschia* sp. and *Acetes* sp. were "common". In January, *Bacillaria* sp., *Coscinodiscus* sp., *Pleurosigma* sp., *Acetes* sp., Amphipod and Copepods were "very common" food items encountered in the diet of *S. longiceps*. *Rhizosolenia* sp. was recorded as a "common" food item as it was found in more than 50% stomachs of *S. longiceps*. In February, *Biddulphia* sp., *Cerataulina pelagica, Coscinodiscus* sp., *Pleurosigma* sp., *Acetes* sp., Amphipod and Copepods were found "very common". *Bacillaria* sp., *Triceratium* sp. and *Dinophysis* sp. recorded as "common" food items. In March, *Bacillaria* sp., *Coscinodiscus* sp., *Rhizosolenia* sp., *Thalassiosira* sp. and *Acetes* sp. were "very common" food items found in more than 75% of the stomachs of the fish. *Pleurosigma* sp., *Thalassionema nitzschioides* and Copepods were recorded as "common" food items.

Index of preponderance

Variation in the index of preponderance (IP) of food items encountered in the stomach of *S. longiceps* during different months revealed that the percentage composition of food items varied monthly according to their availability and occurrence. The monthly variations in the IP are presented in Table 7.

Diatoms formed the most dominant group having an IP of 57.17% in the diet of *S. longiceps* (Table 8). In diatoms, the most dominant was *Coscinodiscus* sp. (18.52%) followed by *Rhizosolenia* sp. (8.86%), *Pleurosigma* sp. (8.38%), *Nitzschia* sp. (8.27%) and *Thalassiosira* sp. (3.87%) (Table 9). Zooplankton formed the second important group (36.51%). In zooplankton, Copepods (27.63%) formed the most dominant food item among all the food items observed in the fish stomachs. Other zooplankton includes *Acetes* sp. (5.40%), Amphipods (2.03%), Tintinnids (0.78%), Foraminifera (0.66%) and Lucifer (0.02%). Dinoflagellates recorded IP of 5.12% with *Ceratium* sp. (2.50%) as the most dominant dinoflagellate followed by *Dinophysis* sp. (1.35%), *Peridinium* sp. (0.82), *Surirella* sp. (0.40%) and *Glenodinium* sp. (0.06%). Unrecognisable matter comprising mud and detritus had an IP of 1.2%.

Index of preponderance on a monthly basis (Table 7) as well as based on different groups of food items (Table 8) indicate that diatoms were dominant throughout the

Table 7. Monthly variations in Index of preponderance of *S. longiceps*

Group	Food item	September 2019	October 2019	November 2019	December 2019	January 2020	February 2020	March 2020
Diatoms	*Asterionella japonica*	-	-	0.01	0.02	0.1	0.46	0.98
	Aulacodiscus sp.	-	-	-	-	-	0.02	1.02
	Bacillaria sp.	0.02	0.04	1.21	0.84	2.61	1.12	6.98
	Bacteriastrum sp.	-	-	0.02	-	-	-	-
	Biddulphia sp.	1.96	0.97	2.44	-	0.01	1.54	0.02
	Cerataulina pelagica	-	-	-	-	0.02	11.35	-
	Chaetoceros sp.	0.13	0.21	0.05	0.31	0.02	0.08	0.12
	Coscinodiscus sp.	21.65	43.42	13.51	12.84	6.51	11.15	20.54
	Fragilaria oceanica	-	-	0.01	-	-	0.38	-
	Nitzschia sp.	3.59	12.18	39.88	1.09	0.81	0.01	0.36
	Planktoniella sol	0.81	0.02	-	-	0.1	-	-
	Pleurosigma sp.	0.9	1.91	7.12	3.99	11.43	20.56	12.76
	Rhizosolenia sp.	46.3	3.09	0.68	0.89	2.15	1.24	7.65
	Skeletonema costatum	-	-	0.84	-	-	-	3.03
	Thalassionema nitzschioides	0.16	2.54	2.65	-	-	0.42	1.27
	Thalassiosira sp.	-	-	0.1	-	0.01	-	27
	Thalassiothrix sp.	-	-	0.03	-	0.02	0.05	-
	Triceratium sp.	0.85	0.29	-	-	1.02	15.68	-
	Total	76.37	64.67	68.55	19.98	24.81	64.06	81.73
Dino-flagellates	*Ceratium* sp.	0.12	7.25	7.97	0.01	-	1.57	0.56
	Dinophysis sp.	0.13	-	4.15	0.48	0.86	1.49	2.34
	Glenodinium sp.	0.03	-	-	0.09	-	0.29	-
	Surirella sp.	0.16	0.26	1.67	0.25	0.19	0.22	0.02
	Peridinium sp.	0.04	0.07	2.77	0.1	0.34	2.06	0.36
	Total	0.48	7.58	16.56	0.93	1.39	5.63	3.28
Zoo-plankton	*Acetes* sp.	4.54	2.5	1.92	2.79	7.98	13.68	4.38
	Amphipod	4.93	1.79	1.04	0.65	2.94	2.85	-
	Copepoda	12.69	17.91	10.1	73.98	60.11	11.06	7.54
	Foraminifera	0.03	1.8	1.34	1.21	0.25	-	-
	Lucifer	-	-	0.04	-	-	0.08	0.02
	Tintinnids	0.04	3.19	0.18	0.01	0.54	1.28	0.2
	Total	22.23	27.19	14.62	78.64	71.82	28.95	12.14
Unrecognisable matter		0.92	0.56	0.27	0.45	1.98	1.36	2.85

Table 8. Index of preponderance of different groups in diet of Indian oilsardine

Food item	IP
Diatoms	57.17
Dinoflagellates	5.12
Zooplankton	36.51
Unrecognisable matter	1.20

Table 9. Index of preponderance of individual food items in the stomach of *S. longiceps*

Food item	IP	Food item	IOP
Acetes sp.	5.40	*Glenodinium* sp.	0.06
Asterionella japonica	0.22	*Lucifer*	0.02
Amphipod	2.03	*Nitzschia* sp.	8.27
Aulacodiscus sp.	0.15	*Surirella* sp.	0.40
Bacillaria sp.	1.83	*Peridinium* sp.	0.82
Bacteriastrum sp.	0.002	*Planktoniella sol*	0.13
Biddulphia sp.	0.99	*Pleurosigma* sp.	8.38
Cerataulina pelagica	1.62	*Rhizosolenia* sp.	8.86
Ceratium sp.	2.50	*Skeletonema costatum*	0.55
Chaetoceros sp.	0.13	*T. nitzschioides*	1.00
Copepoda	27.63	*Thalassiosira* sp.	3.87
Coscinodiscus sp.	18.52	*Thalassiothrix* sp.	0.01
Dinophysis sp.	1.35	Tintinnids	0.78
Foraminifera	0.66	*Triceratium* sp.	2.55
Fragilaria oceanica	0.05	Unrecognizable matter	1.20

study period except in December (19.98%) and January (24.81%). Among diatoms, *Coscinodiscus* sp. formed the most important food item in the month of October (43.42%) and March (20.54%). *Rhizosolenia* sp. was most dominant in the month of September (46.3%), *Nitzschia* in November (39.88%) and *Pleurosigma* sp. in February (20.56%).

Index of preponderance also indicated that zooplankton was dominant in the diet of *S. longiceps* in December (78.64%) and January (71.82%). Among the individual food items, copepods were the most important food item of *S. longiceps* (Table 9). *Acetes* sp. was dominant in February (13.68%). Dinoflagellates dominated in November (16.56%) than zooplankton, while in the remaining months, IP values ranged from 0.48% in September to 7.58% in October. Index of preponderance of unrecognisable matter ranged from 0.27% in November to 2.85% in March.

Cluster analysis

From cluster analysis, it was observed that the highest (83.8%) similarity was observed between December and January months (Fig. 2). September, October and December also fell in the same group indicating the similar diet pattern during these months, while the post-spawning season of March was observed as a totally distant group.

Discussion

S. longiceps is planktivorous fish species feeding mainly on diatoms, zooplankton and dinoflagellates. Antony Raja (1964) reported July-September as the peak spawning period in Kerala, while along the south-west coast, mature and spent gonads were observed throughout the year indicating year round spawning. The peak spawning coincided with the south-west monsoon (June-August) (Rohit *et al.,* 2018). The spawning season of IOS and intense activity during June to September has been reported along south-west coast of India by several earlier workers (Hornell and Nayudu, 1924; Devanesan, 1943; Devanesan and Chidambaram, 1953; Sekharan and Dhulkhed, 1963; Antony Raja, 1972; Balan and Abdul Nizar, 1988; Jayaprakash and Pillai, 2000; Rohit and Bhat, 2003) while an earlier study confirmed an extended spawning period up to December along the north-west coast of India (Motivarash *et al*., 2021). The study reported peak spawning in *S. longiceps* in the region during October. In the present study, *S. longiceps* showed low

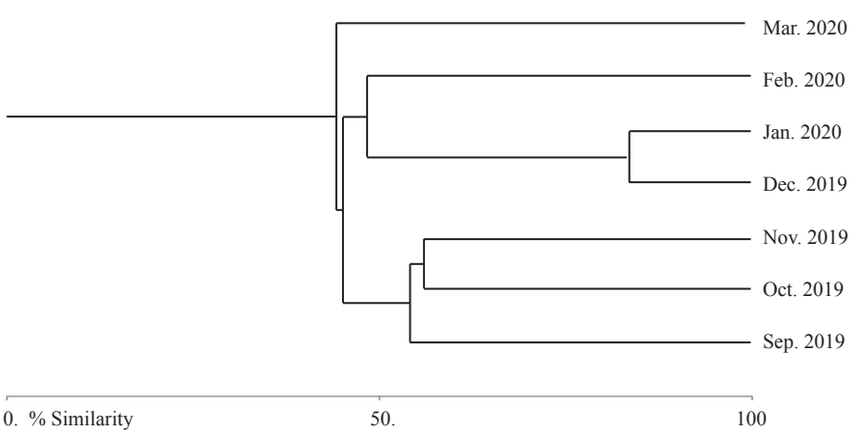

Fig. 2. Cluster analysis showing similarity in *S. longiceps* diet

feeding intensity during the spawning period (September to December) and high feeding intensity in post-spawning period. Similar observations of reduced feeding intensity during spawning had been reported in Maharashtra (Ahirwal *et al*., 2018; Shah *et al*., 2019) while in Gujarat lower feeding intensity was observed during September to October (Rohit *et al*., 2018).

In this study, the decline in feeding intensity was seen more in females than males during the spawning period and fishes fed highly on *Coscinodiscus* sp. and Copepods during peak spawning period of October. Decreased feeding activity during peak spawning season may be result of fully developed gonads, providing less space in the stomach and variations in feeding intensity was more in females than males because the ovaries occupy more space than testes (Mathialagan and Sivakumar, 2012). Kiran and Puttaiah (2004) stated that the reasons for an empty stomach were regurgitation, periodicities in feeding, food availability, physiological reasons, digestibility, health factor and metabolic activity. Most of the clupeid fishes have characteristic change in feeding habits seasonally, with a less or complete decline in feeding during the spawning season and high or intense feeding during the post-spawning period. Scott and Crossman (1973) stated that during spawning period, feeding increased in the clupeid American shad, *Alosa hispidissima*. Stacey and Hourston (1982) also reported increased activity in herrings during the post-spawning period.

The Indian oilsardine feed dominantly on diatoms followed by zooplankton, dinoflagellates and unrecognisable matter. Similar observations have been reported for *S. longiceps* from Karwar (Noble, 1965), Parangipettai (Purusothaman *et al.,* 2014) Mumbai (Ahirwal *et al*., 2018; Rohit *et al*., 2018), Ratnagiri (Shah *et al*., 2019). Diatoms formed an important food item in Mangalore (Dhulkhed, 1962), Trivandrum (John and Menon, 1942) and Calicut (Hornell and Nayudu, 1924). However, the dominancy of diatoms had not been seen in all months as had been reported by other researchers (Kagwade, 1964; Noble, 1965). *Fragilaria oceanica* had been reported as an indicator species of oilsardine (Nair and Subrahmanyan, 1955; Dhulkhed, 1962; Kagwade, 1964). In the present study, *F. oceanica* was rarely observed in certain months, not in sufficient quantity to term it an 'indicator' species. Similar observations defining absence or rareness of *F. oceanica* in the diet of *S. longiceps* had been reported by many authors from different regions of India (Noble, 1965; Dhulkhed, 1972; Remya *et al*., 2011; Shah *et al*., 2019). Copepods contributed in significant amount and were dominating and important in some months as has been also reported by Noble (1965).

The species mainly preferred food items such as *Coscinodiscus* sp., *Rhizosolenia* sp., *Pleurosigma* sp., *Nitzschia* sp., *Thalassiosira* sp., *Acetes* sp. and copepods. Similar to the present study, higher proportion of *Coscinodiscus* sp., copepods, *Pleurosigma* sp. and *Nitzschia* sp. were reported in Maharashtra (Rohit *et al.,* 2018). Temkar *et al*. (2015) reported 133 species of diatoms belonging to 48 genera, 12 species of dinoflagellates, blue-green algae, brown or orange chromatophores and green algae in Veraval waters of Gujarat, while in present study 23 genera were reported in the diet of *S. longiceps*. The absence of numerous phytoplankton species from the diet of *S. longiceps* indicates selective feeding behavior of the fish. The dominance of *Coscinodiscus* sp. in *S. longiceps* diet could be due to its ability to tolerate higher temperatures (Kumar and Balasubrahmanyan, 1987; Rohit and Bhat, 2003; Supraba, *et al.,* 2016; Supraba, 2017). The broad diet width of *S. longiceps* consisting of phytoplankton and zooplankton in the present study confirms results of earlier studies by Temker *et al*. (2015) and Remya *et al.* (2013). The cluster analysis clearly indicated seasonal difference in *S. longiceps* diet. Similar seasonal changes in the diet were observed by Remya *et al.* (2013) and Shah *et al.* (2019).

Acknowledgments

The authors are grateful to Dr. A. Y. Desai, Principal and Dean, College of Fisheries Science, Veraval for providing necessary equipment, facilities and guidance for carrying out this research work. We are also thankful to ICAR-CMFRI, Veraval and its scientific staff for guidance in data collection and analysis.

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Date of Receipt : 08.12.2020
Date of Acceptance : 11.04.2022