DIFFERENCES IN THE FOOD AND FEEDING ADAPTATIONS BETWEEN JUVENILES AND ADULTS OF THE INDIAN OIL SARDINE, *SARDINELLA LONGICEPS* VALENCIENNES

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The food and feeding habits of *Sardinella longiceps*, economically the most valuable clupeiform fish from Indian waters, had been the subject of study for the past five decades (Hornell, 1910; Hornell and Nayudu, 1924; Devanesan, 1943; Chidarbaram, 1950; Nair, 1963; Nair and Subrahmanyan, 1955; Venkataraman, 1960; Dhulkhed, 1962). Although a general idea of the elements on which the oil sardine subsists is worked out, data published on the food-habits of the different stages in its life-span is scanty and doubtful. Chidambaram (1950) opines that the food of young and adult sardines does not differ much. Reference that "immature adults and spawners" feed "mostly on phytoplankton" and "very young sardines" feed mainly on copepods has been made by Nair (1953). Comprehensive study of the differences in the food and feeding habits has not been made by previous workers. Hence the present report on the differences observed in the food and feeding adaptations between juveniles and adults of *S. longiceps* while studying its biology at Cannanore (south-west coast of India) may be of interest.

Material and Methods

Random samples of oil sardine were collected every week from the catches at Cannanore during the period 1961-1963. The total length, gonadial maturity and feeding intensity by displacement method were recorded. Studies were made separately for juveniles and adults in the two seasons, 1961-62 and 1962-63. It may be noted in this connection that the term juvenile is applied to the indeterminate and immature sardines in maturity I-II. The term adult is given to maturing, mature, spawning, spent (stages III-VII), recovering and recovered individuals. It was observed in the present studies that the size at first maturity varies between 130 and 145 mm. total length and from season to season (see Tables I and II).

The gut-contents after being made to a known volume were well stirred up and an aliquot sample of 1 ml. taken by means of a wide-mouthed pipette was spread on a counting slide and the number of each food-item recorded (*Number method*). The various food-elements so counted were evaluated by *Points method* (Hynes, 1950); due consideration was given to the size of the organism and its abundance.

While studying the stomach contents of the oil sardine, fish scales and sand-particles were observed in some cases. The former were found as a column in the anterior region of the oesophagus indicating that they are accidental inclusions. Sand-particles were observed in the samples examined from *mathi-kolli-vala* units (boat seine), in which the population is fished under panic impulse and the catch confined to a limited shallow sandy area. Obviously, such accidental and fortuitous inclusions do not form the normal diet (see Pillay, 1952; Pradhan, 1956; George, 1964) and are not included in the present study.

Feeding Intensity of Juveniles and Adults

The average volume of food consumed during the seasons 1961-62 and 1962-63 by juveniles and adults shows a similar trend of fluctuation (Tables I and II). A high feeding activity can be observed from July-August to October-November, a decreasing trend from November-December to February-March, reviving to a higher trend in the March-April period. The months of November-December to February-March are the periods of lowest feeding activity both for juveniles and adults. It may be noted in this connection that this also is the season of lowest plankton production in the coastal Arabian Sea (George, 1953; Subrahmanyan and Sarma, 1960). Off Cannanore also the production was low during this period as can be seen from figure 1.

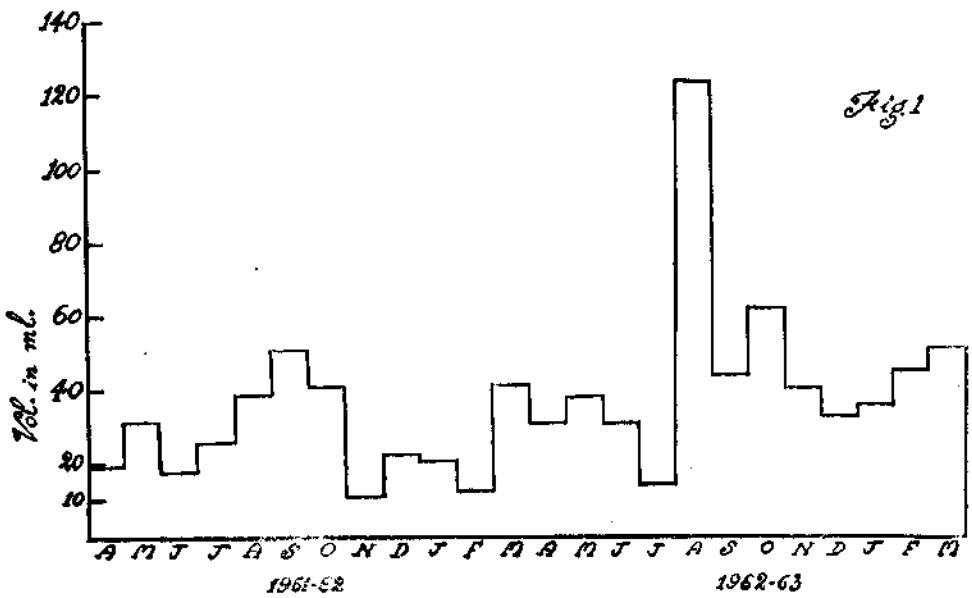

Fig. 1. Monthly displacement volumes of the total plankton off Cannanore during the seasons 1961-1962 and 1962-1963.

QUALITY OF THE FOOD CONSUMED BY JUVENILES AND ADULTS
(Figs. 2*a* and 2*b*)

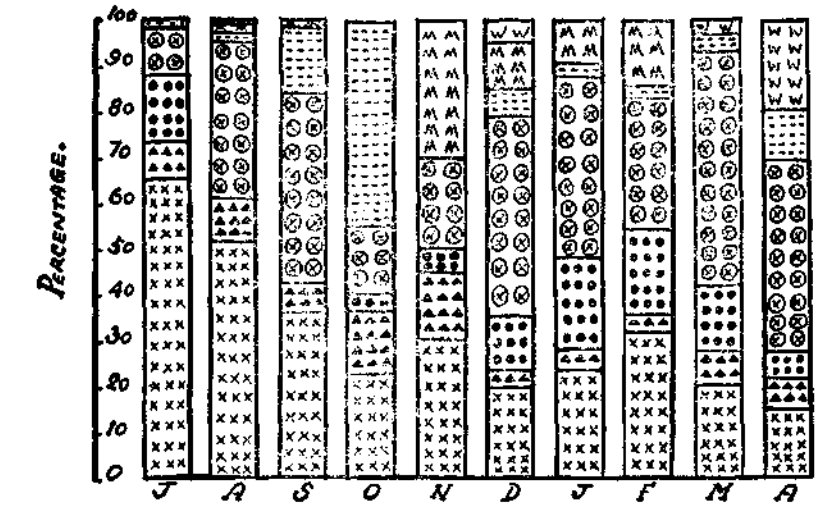

Fig. 2a

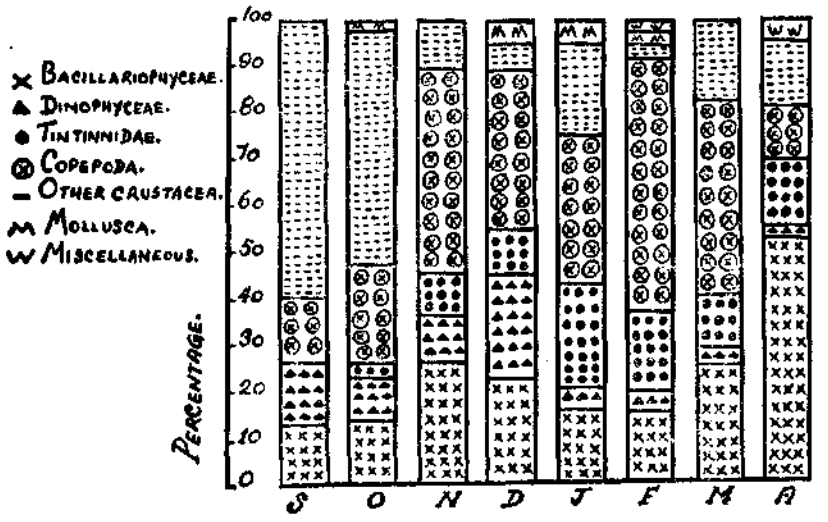

Fig. 2b

FIG. 2—Average percentage composition of the different food-elements in the diet of adult 2 (a) and juveniles 2 (b) oil sardine during different months of the seasons 1961-1962 and 1962-63.

Bacillariophyeae: —

This group comprising the diatoms dominated the food of adults in July-August but was in low proportions during September in the diet of both juveniles and adults. In November-February they were moderately fed upon

TABLE I

Size-range of oil sardine juveniles and adults along with their maturity stages and monthly average volume of food for the season* 1961-62

Month	July		August		September		October		November	
J (=juveniles) A (=adults)	J	A	J	A	J	A	J	A	J	A
Size-range (in mm.)	..	..	140—189		51—94	150—189	80—134	155—179	90—134	..
Maturity stage	..	..	III—VIb		** In.	III-VIb	In-I	*** Re. I-II	I	..
Average volume of food (in ml.)	..	..	0.24		0.02	0.17	0.10	0.28	0.06	..

TABLE I—*Contd.*

Size-range of oil sardine juveniles and adults along with their maturity stages and monthly average volume of food for the season* 1961-62

Month	December		January		February		March		April	
J (=juveniles) A (=adults)	J	A	J	A	J	A	J	A	J	A
Size-range (in mm.)	90—134	150—175	95—139	155—190	105—135	155—190	105—140	..	120—145	155—185
Maturity stage	In-I	Re. I-II	I-II	Re.II	I-II	Re.II	II	..	II	Re.II
Average volume of food (in ml.)	0.03	0.04	0.03	0.05	0.05	0.04	0.13	..	0.14	0.18

*Maturity stages determined as given by Lovern and Wood (1937).

**"In" indicates indeterminates.

***"Re" indicates recovered after spawning.

TABLE II

Size-range of oil sardine juveniles and adults along with their maturity stages and monthly average volume of food for the season 1962-63

Month	July		August		September		October		November	
J (=juveniles) A (=adults)	J	A	J	A	J	A	J	A	J	A
Size-range (in mm.)	130—199		145—179		51—84	150—179	90—144	155—189	110—144	155—189
Maturity stage	IV—VII		IV—VII		In.	V—VII	In-I	Re.I-II	I	Re. II
Average volume of food (in ml.)	0.26		0.44		0.02	0.12	0.11	0.21	0.07	0.09

TABLE II—*Contd.*

Size-range of oil sardine juveniles and adults along with their maturity stages and monthly average volume of food for the season 1962-63—Contd.

Month	December		January		February		March		April	
J (=juveniles) A (=adults)	J	A	J	A	J	A	J	A	J	A
Size-range (in mm.)	110—144		110—144	165—189	115—144	150—194	114—138	145—178		160-189
Maturity stage	I		I-II	Re. II	I-II	Re.II	II	Re.II		Re. II
Average volume of food (in ml.)	0.04		0.06	0.14	0.07	0.15	0.13	0.36		0.23

"In" indicates 'indeterminates' and "Re", 'recovered after spawning'.

by adults and found in increasing proportions in the food of juveniles subsequent to February. The important forms present included *Thalassiosira, Coscinodiscus, Fragilaria, Pleurosigma, Thalassiothrix, Thalassionema, Nitzschia, Biddulphia, Rhizosolenia, Planktoniella* and *Triceratium.*

Dinophyceae :—

The 'edible' dinophysids contributed only to a minor proportion of the food of both juveniles and adults. The important items present were *Ceratium, Peridinium, Dinophysis, Pyrophacus, Prorocentrum* and *Ornithocercus.*

Tintinnidae :—

During November-March this group formed a minor proportion of the food. The common forms were *Tintinnopsis, Codonella* and *Cyttarocylis.*

Copepoda :—

Copepods formed an important component of the food of oil sardine, both juveniles and adults, almost throughout.

Other crustacea :—

Non-copepod items and crustacean larval stages, chiefly nauplius, cypris and protozoea were predominant in the diet of juveniles during September-October, while they appeared in good numbers in the food of adults during October.

Mollusca :—

Larval bivalves were found in a few numbers from November to March.

Miscellaneous :—

The myxophycean *Trichodesmium* and members of Radiolaria were occasionally found in the diet of oil sardine. A partly digested polychaete was recorded on one occasion while on another a few 'inedible' *Noctiluca* were observed.

Differences in the Food Between Juveniles and Adults

Although the general pattern of feeding in juveniles and adults appears to be the same, a scrutiny of the food-items reveals a differential mode of feeding between the two. The juveniles have fed more on a crustacean diet than on phytoplankton. On the other hand the latter forms a predominant food of adults, the crustacean elements being of subsidiary importance. The higher carcinivorous tendency of the juveniles becomes less and less marked as they grow older. For instance in the 51-94 mm. group of September 1961 crustacean elements formed 88% but in the 95-139 mm. group of January 1962 only

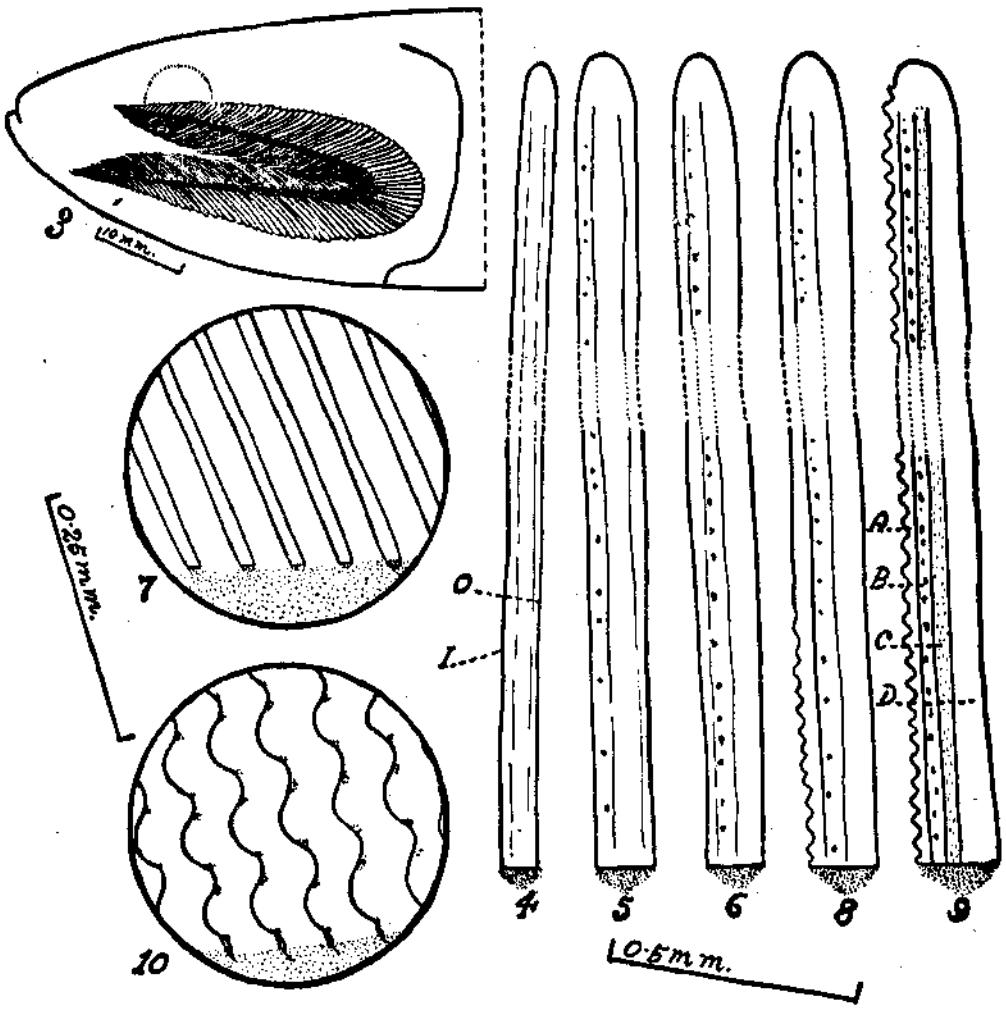

FIG.—3-10—Drawings of the gill-rakers in juvenile and adult oil sardine. Fig. 3 the first branchial arch *in situ* of a specimen of 165 mm. long showing the gill-rakers; Figs. 4, 5 and 6 gill-rakers of specimens 51, 61 and 75 mm. long respectively; Fig. 7 semidiagrammatic sketch of the sieving area of a specimen of 53 mm. magnified; Figs. 8 and 9 gill-rakers of specimens 80 and 179 mm. long respectively. Fig. 10 semidiagrammatic sketch of the sieving area of a specimen of 181 mm. magnified. A. Zone of papillae, B. Zone of pigments, C. Zone of cornification, D. Zone of clear area, I. inner lateral margin, O. outer lateral margin.

50%. In the case of adults the crustacean contribution was very low: thus in the 150-189 mm. group of September 1961 it was 40% and in the 155-190 mm. group of January 1962, 35%.

Side by side with this a tendency is observed in juveniles to feed more and more on phytoplankters with progressive growth. Thus they have formed

only 12% in the diet of the 51-94 mm. group of September. 1961, while almost double the quantity (23%) in the case of the 95-139 mm. group of January '62.

Differences in Feeding Adaptations

Differences observed in the food have led to a study of the gill-rakers which constitute the food-sieving organs in the oil sardine (Fig. 3). Each raker is a dorsoventrally flattened, long, blade with an unpigmented outer lateral margin facing the opercular chamber and an inner lateral margin, which is invariably pigmented, facing the pharyngeal cavity. The free ends of the rakers are directed anterio-dorsally and the inner lateral margins medio-dorsally. A study of their structure in the different size-groups shows that in the 51-75 mm. sardines the rakers are short, simple in structure, unsturdy and feebly pigmented with even lateral margins (Figs. 4-6). Very narrow interspaces are present between the rakers (Fig. 7). In an 80 mm. long juvenile, a few conical papillae have made their appearance along the inner lateral margin in the proximal region of the rakers (Fig. 8) About this size the sardines show a gradual increase in the number of papillae and density of pigmentation. Thus in a 179 mm. long adult the entire inner lateral margin of the rakers is provided with closely arranged papillae (Fig. 9).

The gill-rakers in the adults are broader, longer, stronger and sturdier than in the juveniles. An adult raker has four zones along its transverse axis: an outer clear unpigmented area, a zone of cornification which gives skeletal support, a layer of pigments and the inner margin bearing the papillae (fig. 9). Such a zonation is wanting in 50-80 mm. sardines and under progressive development in the 80-140 mm. group but fully developed above this size. The rakers in the adults are so disposed that the papillae of one raker overlap the outer-lateral margin of the raker below it (Fig. 10). The seiving area in the adults *in-situ* presents the appearance of a tight strainer with innumerable papillae over it.

Discussion

The process of feeding in filter-feeding clupeids is different from the process in filter-feeding whales in which the planktonic food that goes into the pharynx is automatically sieved by the baleen plates. Kishinouye (1907) working on *Sardinops melanosticta* expressed his belief that sardines to some extent can select their food by manipulation of their gill-rakers. *Clupea harengus* is observed to select its favourite food *Calanus* from among its other food-elements like *Sagitta* and *Limacina* in the plankton (Hardy, 1959). Species of *Sardinella*, according to Vijayaraghavan (1953) "can be described as surface feeders and may be called plankton predators". Ganapati and Rao (1957) studying the foot-habits of *Sardinella gibbosa* opined that the species appears "to exercise a definite action of capture 'involving quick efforts on the part of the fish' ".

Workers on *S. longiceps*, hitherto, have mostly "described its food as consisting of plankton, predominantly phytoplankton and they inferred that they are filter-feeders in habit" (Ganapati and Rao, 1957). That the oil sardine is surface and/or column feeder is evident from the planktonic nature of its diet. Devanesan (1943) suspected bottom feeding for the oil sardine inhabiting Bombay waters. This author had not taken into consideration the type of gear and mode of capturing the fish sampled by him; hence his observation is open to question. Venkataraman (1960) has noted that the presence of sand-grains in the food of oil sardine "may be accidental as it is a surface feeder".

Differences observed in the food and feeding adaptations between juveniles and adults in the present study strongly suggest one or both of the following operating individually and/or collectively during the process of feeding:—

In the first instance the fully developed filtering mechanism of the adults seems to sieve efficiently both the very minute diatoms, dinophysids etc. and the large-sized copepods, crustacean larvae etc. The imperfectly developed filtering apparatus of the juveniles, on the other hand, appears to exercise an indirect selection more for the large-sized items, while an appreciable quantity of the minute organisms, though filtered to some extent have a higher chance of "being carried out again by the stream of water flooding through the gills". While it is true that swarms of minute organisms can also be sieved in the mesh that would catch the large forms, the efficiency will be relatively of a less degree in juveniles than in adults. This is supported by the example of the minute organisms (diatoms and dinophysids) forming only 12% in the diet of juveniles (51-94 mm. group) and as high as 58% in the diet of adults (150-189 mm. group) during the month of September 1961.

The second probability is that the juvenile sardines are predominantly carcinivorous and with growth they become mostly phytoplanktonic in habit. It is not improbable that the juveniles are to a large degree predators on planktonic crustaceans, their gill-rakers manipulating to catch more of them; and with growth less and less so; the adults consuming more of phytoplankters, their gill-rakers manipulating to catch more of them. In that case the presence of crustacean elements and phytoplankters in the environment would decide, although to a certain extent, the abundance of juveniles and adults respectively in the fishery.

Summary

Juvenile oil sardine (50-130/145 mm. group) are observed to feed chiefly on a carcinivorous diet, while adults (130/145 mm. and above) mostly on phytoplankton.

The gill-rakers are either imperfectly developed (50-80 mm. group) or under progressive development (80-130/145 mm. group) in juveniles, while in adults (130/145 mm. and above) they are fully formed, being an efficient sieve.

One or both the probabilities that the carcinivorous tendency of the juveniles is due to an indirect selection for the large-sized items by their inefficient filtering mechanism while the predominantly phytoplanktonic diet of the adults is due to their efficient sieving of the minute organisms; and that the juveniles are chiefly predators on planktonic crustaceans and adults mostly on phytoplankters, being in operation during the process of feeding have been pointed out.

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