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INDIAN SARDINES

(THEIR BIOLOGY AND FISHERY)

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PREFACE

Zoology is a subject of study in the majority of our universities and colleges, both at the undergraduate and post-graduate levels. Several of the university departments are engaged in original research in different fields. Generally, teaching and research have gone together and India's contribution to the growth of knowledge in zoology is not inconsiderable. Many of these contributions find publication in Indian and foreign scientific journals.

The Council of Scientific & Industrial Research felt that in this dual function of teaching and research in biological sciences, the Council could assist in the production of suitable literature for the use of teachers and research workers. With this in view, in 1963, a Zoological Monographs Committee was constituted by the CSIR to concert measures for bringing out these publications, and I was invited to be the Chairman.

The Committee met several times and two series of publications were envisaged: (i) MEMOIRS on Indian Animal Types, to serve as guides for teaching in colleges and university departments; (ii) MONOGRAPHS on selected subjects of special interest to advanced students and research workers. The Committee selected suitable topics under these two series of publications and specialists were invited to write on them. Ten topics were chosen under each series.

Indian Sardines is the second in the series of Zoological Monographs, issued by the CSIR and has been written by Dr R. V. Nair, Deputy Director, Regional Centre of Central Marine Fisheries Research Institute, Mandapam Camp (Tamil Nadu). Dr Nair has been engaged in the Sardine Research Programme of the Institute for over two decades, and has published a number of papers in Indian and foreign periodicals. It is hoped that this monograph will prove useful to teachers, post-graduate students and research workers in the field.

New Delhi
28 December 1972

B. R. SESHACHAR

AUTHOR'S NOTE

In the world marine fisheries at large as well as in the Indian fisheries the clupeoid fishes occupy a unique position. The contribution of this group to the marine fish production of this country is about one-third, of which the Indian oil sardine, *Sardinella longiceps* Cuv. & Val. forms a major share. The fluctuations in this fishery, both seasonal and annual have rendered it undependable for commercial exploitation. Even though investigations were commenced some three decades ago with a view to elucidate the causes behind the fluctuation, precise information relating to many of the fundamental aspects of the biology of the fish, namely, the food and feeding habits, embryonic and larval development, spawning habits, age and rate of growth, became available only during the last two decades.

The importance of the lesser sardines as a valuable fishery resource on both the coasts of India has been realized in recent times and a number of scientific papers have been published on their biology and fisheries.

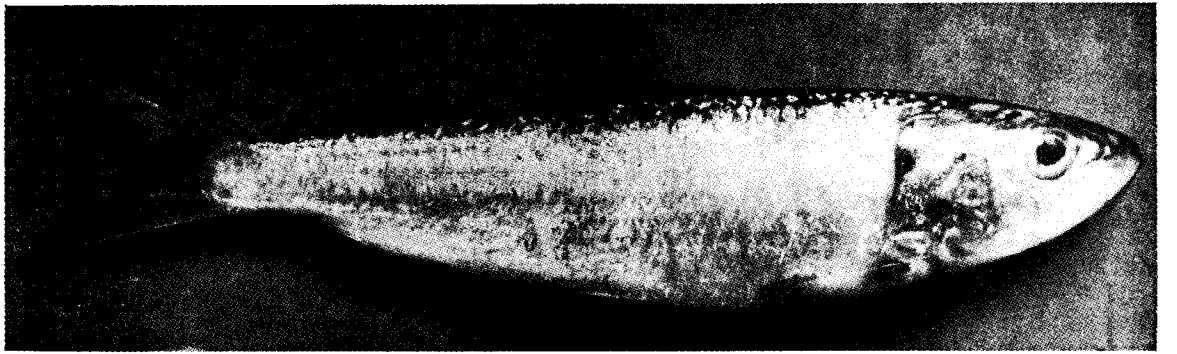
The author has been interested in Sardine investigations since 1947 and has studied problems like taxonomy, various aspects of biology such as age and growth, food and feeding habits, reproduction, early life-history, bionomics and fisheries. The results of his investigations on the oil sardine, white sardine and other lesser sardines have been published in various scientific periodicals, both foreign and Indian. A 'Synopsis on the Biology and Fishery of the Indian Sardines' was prepared and published in the Proceedings of the World Scientific Meeting on the Biology of the Sardines and related species held under the auspices of FAO during 1959 at Rome.

As the Chief of the Sardine Research Programme at the Central Marine Fisheries Research Institute, Mandapam Camp (Tamil Nadu) for several years the author had co-ordinated the various research projects, and it was felt necessary to bring out all the available information in a monographic account, in order to highlight the achievements made on the various aspects of the biology and fishery of the different sardines and to facilitate planning and undertaking of research work in areas which require further study and investigation.

Mandapam Camp
12 May 1972

R. V. NAIR

LIST OF ILLUSTRATIONS



The Indian Oil Sardine, *Sardinella longiceps* Cuv. & Val.

INDIAN SARDINES

INTRODUCTION

Among the commercial food fishes of the world, the clupeoid fishes (Class *Teleostomi*, Order *Clupeiformes*) are second to none, and the South American anchovy, European and American herrings, pilchards, sardines, etc. make the largest contribution to the fisheries and form the mainstay of the economy of most of the maritime nations. In India, the clupeoids which contribute about a third of the marine fish production, are chiefly represented by the sardines, anchovies and white-baits. Of these the sardines of the genus *Sardinella* are represented in our waters by nine species of which a few like *S. longiceps* Cuv. & Val., *S. fimbriata* (Cuv. & Val.), *S. gibbosa* (Bleeker) and *S. albella* (Cuv. & Val.) occur in enormous shoals and form important fisheries along both the coasts of India.

The abundant occurrence of the oil sardine, *S. longiceps* (Cuv. & Val.) along the west coast and its use as food and manure had been known from very early times and the fish has been rightly referred to as *kudumbam pularthy* (provider for the family) in the Malayalam language. The disastrous failure of the oil sardine fishery during the forties of this century focussed attention on the necessity for initiating investigations to determine the factors which control and influence the seasonal migrations and annual fluctuations encountered in the fishery. Pioneering work in this direction has been done by the early workers (Hornell, 1910; Hornell & Nayudu, 1924; Devanesan, 1943) and their valuable contributions have been reviewed twice by Nair in 1951b and 1960. A number of papers dealing with different aspects of the oil sardine and its fishery have been published subsequently by a team of workers of the Central Marine Fisheries Research Institute, Mandapam Camp (Tamil Nadu). But unfortunately the contradictory views expressed by them have created a certain amount of confusion, resulting in the lack of precise information regarding different aspects of the biology and fishery of the oil sardine.

The need for intensive biological research to solve the various problems involved in the commercial pelagic fisheries was stressed by Sette (1949) and Panikkar (1952). At the 'World Scientific Meeting on the Biology of Sardines and Related Species' held under the auspices of FAO at Rome, in 1959, a number of synoptic accounts of the various species of the sardines of different regions of the world have been presented. Important among the papers are those by Nair (1960), Li (1960), Ronquillo (1960) and Soerjodinoto (1960).

There has been a gradual decline in the landings of almost all the important commercial fisheries, barring the sardine fishery, indicating the likelihood of overfishing and this is attributed to the intensive fishing carried out at present in the inshore waters without extending the field of operation to the offshore regions (Nair, 1970). A national co-operative research programme on the oil sardine is required to be set up urgently in view of its great contribution to the overall marine fish production in the country.

Taxonomy

The classification of clupeoid fishes, just like other fish groups has been a challenging subject to the taxonomist. During the last six decades different workers have put forth various classifications, the important among which are those by Weber and Beaufort (1913), Regan (1917), Berg (1940), Herre (1953), Whitehead (1965, 1967) and Chan (1965). According to Weber and Beaufort (1913) the order Malacopterygii includes eight families of which one family, viz. Clupeidae includes the sardines. The family Clupeidae comprises five subfamilies, viz. Clupeinae, Dussumierinae, Dorosomatinae, Engraulinae and Chirocentrinae. Six genera, namely *Corica* Hamilton Buchanan, *Clupeoides* Bleeker, *Clupea* Linn., *Pellona* Cuv. & Val., *Opisthopterus* Gill and *Raconda* (Gray) Cantor are recognized under the subfamily Clupeinae. The genus *Clupea* Linn. includes the following three subgenera *Amblygaster* Bleeker, *Alosa* Cuv. and *Harengula* Val.

Berg (1940) recognized three subfamilies, viz. Dussumieriini, Clupeini and Dorosomatini under the family Clupeidae.

According to Herre (1953) the family Clupeidae comprises five genera, viz. *Ilisha* Richardson, *Sardinella* Cuv. & Val., *Alosa* Cuv., *Harengula* Cuv. & Val. and *Clupeoides* Bleeker. Eleven species are recognized by him under the genus *Sardinella*.

According to Whitehead (1967) the family Clupeidae includes the following five subfamilies: Clupeinae, Pellonulinae, Pristigasterinae, Alosinae and Dorosomatinae. In the Indo-Pacific region five genera, viz. *Herklotsichthys* Whitley, *Sardinella* Cuv. & Val., *Escualosa* Whitley, *Sardinops* Hubbs, and *Clupea* Linn. are recognized by him under subfamily Clupeinae.

Chan (1965) in his revision of the Indo-Pacific clupeid fishes of the genus *Sardinella* treated "the group conservatively as a single genus with two subgenera, *Amblygaster* and *Sardinella*". Under the subgenus *Sardinella* he has recognized fifteen species of which nine species occur in the Indian region.

Several workers (Weber & Beaufort, 1913; Regan, 1917; Herre, 1953) have recognized *Dussumieria acuta* Cuv. & Val. and *D. hasselti* Bleeker as valid species but Whitehead (1963) has treated the latter species as synonym of the former species. The present author is of the opinion that the two have to be treated as separate species, for, the characters like the head length, height of body and the length of the maxillary and pectorals show distinct differences.

Regarding the nomenclature of certain species various authors have used different names. For example, Whitehead (1965) has adopted the specific

names *albella* and *gibbosa* whereas Chan (1965) has used the names *perforata* and *jussieu*. Similarly, while Fowler (1941) and Munro (1955) have used the name *Kowala coval* (Cuv.), Whitehead (1967) calls it *Escualosa thoracata* (Val.). In the present account the author has adopted the widely used names to avoid confusion. In regard to dual authorship of Cuvier and Valenciennes credited to some species, divergent views have been expressed by specialists in the field. Though some of the recent workers (Munro, 1955; Whitehead, 1965) have followed single authorship, Chan (1965) has retained the dual authorship. The present author also has followed the dual authorship of Cuvier (Cuv.) and Valenciennes (Val.).

SYNOPSIS OF SPECIES

The following key to the identification of Indian sardines of the genus *Sardinella* Cuv. & Val. is based on Regan (1917):

I. Ventral scutes sharply keeled	
A. Pelvic fins 9-rayed; a dark spot at edge of operculum	
Eye 5-6 in length of head, which is 3-3.6 in length of fish; 180-250 gill-rakers on lower part of anterior arch	1. *longiceps* (Cuv. & Val.)
B. Pelvic fins 8-rayed; a dark spot at base of anterior rays of dorsal fin	
Depth 2.75 in length; 130 gill-rakers on lower part of anterior arch	2. *dayi* (Regan)
Depth 2.5-3; gill-rakers 55-65; diameter of eye 3 to 3.3 in length of head	3. *albella* (Cuv. & Val.)
Depth 3-3.5; gill-rakers 70-75	4. *fimbriata* (Cuv. & Val.)
Depth 3.25-4; gill-rakers 58-62	5. *sindensis* (Day)
Depth 3.5-4; gill-rakers 50-55	6. *gibbosa* (Bleeker)
Depth 3.5-4; gill-rakers 38-44	7. *melanura* (Cuvier)
II. Ventral scutes feebly keeled	
Maxillary nearly or quite reaching to below eye; 36-40 gill-rakers on lower part of anterior arch; pelvics below anterior half of dorsal	8. *sirm* (Walbaum)
Maxillary not reaching eye; 27-31 gill-rakers on lower part of anterior arch; pelvics below origin of dorsal	9. *clupeoides* (Bleeker)

BIOLOGY OF THE OIL SARDINE

Sardinella longiceps Cuv. & Val. syn. *Sardinella longiceps* Cuv. & Val., 1847; Regan, 1917; Fowler, 1941; Herre, 1953. *S. neohowii* Cuv. & Val., 1847; Day, 1865. *Alausa scombrina* Cuv. & Val., 1847. *Clupea longiceps* Günther, 1868; Day, 1878, 1889. *C. scombrina* Günther, 1868; *C.* (*Harengula*) *longiceps* Weber & Beaufort, 1913.

Malayalam: *Mathi, Nalla mathi*; Kannada: *Buthai*; Marathi: *Tarali, Haid*; Telugu: *Noone-kavallu*; Tamil: *Nonalai.*

Description

Depth of body 4-4.7 in the length; length of head 3-3.6. Snout longer than diameter of eye, which is 5-6 in length of head; maxillary extending to below anterior part or nearly to middle of eye; 180-250 gill-rakers on lower part of anterior arch. 46-48 scales in a longitudinal series; 12 or 13 in a transverse series. Ventral scutes sharply keeled, 18-21+13-15. Dorsal 16-18. Anal 14-16. Pelvic 9-rayed, below or behind middle of dorsal. A dark spot at edge of operculum. Vertebrae 47 (Regan, 1917).

Visceral Organs

The important organs (Fig. 1) found in the body cavity of the oil sardine, *Sardinella longiceps*, are those associated with the digestive system, respiratory system, circulatory system, excretory system and the reproductive system. In addition to these, there is the hydrostatic organ namely the swim-bladder or the air-bladder.

The mouth is terminal and is situated at the anterior extremity of the head. The buccal cavity leads into the pharynx and on either side of the pharynx

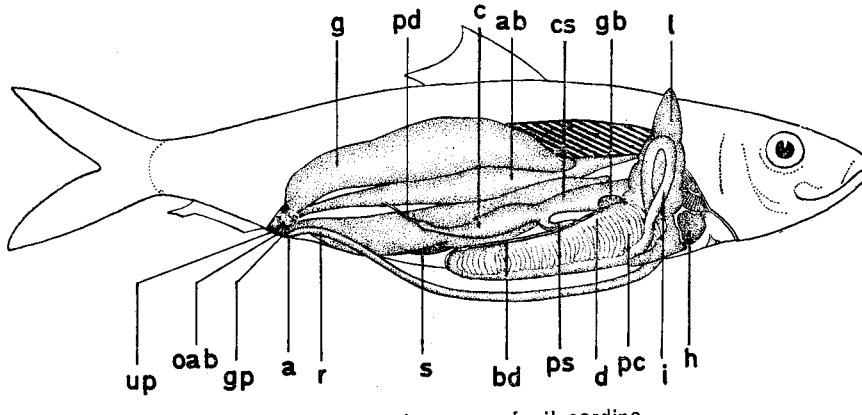


Fig. 1 — Visceral organs of oil sardine
a, anus; ab, air-bladder; bd, bile duct; c, caecum; cs, cardiac stomach; d, duodenum; g, gonad; gb, gall bladder; gp, genital pore; h, heart; i, ileum; l, liver; oab, opening of air bladder; pc, pyloric caecae; pd, pneumatic duct; ps, pyloric stomach; r, rectum; s, spleen; up, urinary pore

four pairs of gills are found. The pharynx in *S. longiceps* is provided with a pair of pharyngeal organs, situated on either side of the median line and above the hinder region of the suprabranchial chamber. These pockets are curved, blind tubes each of which opens into the pharynx by a large aperture and also into the peribranchial chamber (Bensam, 1964b). The oesophagus is short, funnel-shaped, and leads into the stomach. The stomach is large and has two parts, viz. the cardiac stomach and the pyloric stomach. The former is drawn out into a large caecum, and the latter starts from the junction of the cardiac stomach and the caecum, and it is club-shaped and thick-walled with the proximal part narrow and the distal part wide. It lies parallel to the cardiac stomach. The pyloric stomach is followed by the duodenum which extends backwards up to the posterior end of the caecum and it again extends forwards as the ileum. Starting from the junction of the duodenum with the pyloric stomach and throughout the ventral side of the former are present numerous small, blind, glandular tube-like processes called pyloric caecae. These are longer near the proximal part of the duodenum and become shorter towards its distal end. The ileum is long and forms coils, and two such coils are present in the anterior part of the body cavity, one on each side. The ileum proceeds posteriorly along the mid-ventral line and ends in the rectum which opens to the outside by the anus. The pyloric stomach, duodenum, pyloric caecae and the coils of the ileum form a compact mass which is kept in position by mesenteries.

The liver has three main lobes, one on either side and the third on the ventral side, and covers the anterior part of the intestinal mass. The gall bladder is situated below the base of the right lobe of the liver and the bile duct starting from it passes along the dorsal side of the duodenum and opens into the latter at its distal end. The pancreas is diffuse and lies in the mesentery. The spleen is an arrowhead-shaped dark red mass which lies just posterior to the duodenum and in between the intestine and the cardiac caecum.

The essential organ of the circulatory system namely the heart is situated in the pericardial chamber and is placed below the pharynx, immediately behind the gills and in front of the liver.

The other important organs found in the body cavity are the kidneys, gonads and the air-bladder. The kidneys are situated immediately below the vertebral column and these are long thin glands which are dark red in colour and excretory in function. The excretory products pass out through the urinary duct which opens to the outside by an aperture just behind the genital pore on the urino-genital papilla.

The reproductive organs, the gonads, are in the form of two lobes, one on either side. The right lobe is slightly smaller than the left and the gonoducts of both the lobes unite to form a common duct which opens out through the genital pore centered on the urino-genital papilla situated just behind the anus.

The air-bladder or swim-bladder is a simple, fusiform, thin-walled sac placed obliquely in the abdominal cavity below the kidneys. It possesses

a prominent pneumatic duct which opens into the tip of the caecum of the cardiac stomach (Dehadrai, 1962). The duct swells up to form a bulbous structure near the caecum. The air-bladder opens to the exterior to the left of the genital and urinary pores. The swim-bladder extends in front in the form of a pair of air-ducts to establish the ear-swim-bladder relationship as observed by O'Connell (1955) in *Sardinops caerulea* (Girard).

The anus, genital pore, urinary pore and the opening of the air-bladder are all situated in a common subcutaneous pit. Behind the anus there is a broad urino-genital papilla with the genital pore in the centre. The urinary pore is immediately behind it while the opening of the air-bladder is on the left side of the genital pore.

Distribution

Arabia, Mombasa, Seychelles, Iran, Pakistan, India, Ceylon, Java, Bali Straits and Philippines.

General Variability — Races

A detailed study of the oil sardines occurring along both the coasts of India at different times of the year was made by Hornell and Nayudu (1924) and they believed that local races are absent in Malabar and South Kanara owing to the stability of the main external characters like length of head and height in relation to body length.

Devanesan and Chidambaram (1943) made a comparative study of the morphometric characters of oil sardines obtained from Bombay-Karachi, Muscat, Aden and Karwar. The Karwar oil sardines possess the longest head while the Aden, Bombay-Karachi, Muscat and Malabar oil sardines showed decreasing head lengths. On the other hand, the Karwar sardines possessed the shortest tail and its length increased successively in the Aden, Malabar, Bombay-Karachi and Muscat oil sardines. In view of these differences Devanesan and Chidambaram tentatively concluded that more than one race is present in the oil sardine population. Since the Karwar oil sardines showed the longest head and the shortest tail the authors suggested that they belong to a distinct race wedged in between the Malabar race and the Bombay-Karachi race which in turn separates the Muscat race from the Indian west coast races of oil sardines. They inferred that the Aden oil sardines showing the second longest head and tail might be an outlying race by itself. They also made a study of the variations in the number of rays in the right pectoral, dorsal and anal fins.

Devanesan (1943) made a detailed study of the characters of the Bombay-Karachi and Malabar oil sardines and found that the length of the head in the former is about 3.82 in total length while this ratio is 3.63 in the latter. He also noticed that the tail is long in the Bombay-Karachi oil sardines. In addition to these differences, he found the presence of 15 to 17 rays in the pectoral fin of the Bombay-Karachi oil sardines while the Malabar oil sardines showed only 15 rays. A detailed examination of the stomach contents of

the oil sardines of the Bombay-Karachi zone was also made by him and he found the presence of uniformly-sized sand grains in large quantities which was attributed to the bottom feeding habits of the oil sardines of this zone. He favoured the view that the Bombay-Karachi oil sardines belong to a distinct local race.

Nair and Chidambaram (1951) suggested that this aspect requires further careful examination since the existence of distinct races in the oil sardine, if proved conclusively, has an important bearing on the investigations relating to the biology and fishery of the oil sardines.

Differential Distribution

The early life-history of the oil sardine has been studied (Nair, 1959) and there is very little information available about the areas of distribution of the eggs, larval and post-larval stages of the oil sardines. The eggs of oil sardine have been recorded from Tanur (Sundara Raj, 1936), Quilandy (Devanesan, 1943) and Kozhikode (Nair, 1953b, 1959). About the period of occurrence, Nair (1953b) stated that oil sardine eggs were common in the plankton collections made off Kozhikode during August and September 1948, November 1949 and August and September 1950.

Seasonal Variation

The pioneering investigations carried out by Hornell in 1910 showed that the shoals of oil sardines arriving by the end of June consist entirely of adult individuals with mature gonads and that they are seen till the end of August after which the shoals consist entirely of spent individuals. He also pointed out that the shoals arrive inshore in the order in which their gonads ripen and the sardines with gonads in the advanced stage of maturity are the earliest to enter the coastal waters. He inferred that the sardines after spawning rapidly grow fat and in September these fat-laden sardines are caught in enormous numbers especially during the subsequent months, namely October to December. He stated that the same cycle of events occur in the east coast also up to the Ganjam coast where shoals of oil sardines appear towards the end of September and disappear by the end of April. He believed that the appearance and disappearance of the shoals from the deep waters to the shallow coastal waters, and vice versa as a normal annual migration and pointed out that this inshore and offshore migrations in the different months synchronized with the prevailing wind conditions. He indicated that the inshore migration of the adult spawners is for feeding on the luxuriant growth of diatoms found in the coastal waters at that time.

According to Hornell and Nayudu (1924), the oil sardines after attaining maturity leave the inshore waters just prior to spawning which takes place during June to August — once only in a year. The young sardines migrate to the shallow inshore waters in August and September to feed upon the immense quantities of microplankton found in the coastal waters towards the close of the south-west monsoon till the end of the year.

Chidambaram (1950) made a detailed study of the length frequency of the oil sardine extending from 1936-37 to 1942-43 seasons and he found that the fishery of each season is composed of oil sardines belonging to different size groups representing different generations. He traced their entry into, progression through and eventual disappearance from the fishery of the successive seasons. He pointed out that the oil sardines appear first in the Kozhikode zone and then appear gradually in succession towards the north and begin disappearing in the north and then near about Kozhikode and finally in the south. He noticed a slight mixing up of the period of appearance in the Kozhikode and the southern zones. A similar observation was made by Sekharan and Dhulkhed (1963) in the Mangalore zone where the fishery starts in the southern centres and gradually extends to the northern centres. On the other hand, Hornell (1910) noticed the shoals of oil sardines arriving along the South Kanara coast earlier than along the Calicut and Cochin coasts. Chidambaram (1950) also correlated the sequence of appearance of oil sardine shoals with the average surface temperature of sea water during different months. He observed an increase in temperature from the southern to the northern areas after July when the temperature is relatively low, viz. 25.9°C. He found a correlation between the gradual increase in temperature from south to north and the appearance of the oil sardines from the southern to the northern zones and their final disappearance from north to south in the same retrogressive manner.

Nair (1953b) made a detailed study of the oil sardine fishery for a few seasons and he observed a clear difference in the zonal distribution of the oil sardine population at Malpe and at Kozhikode as shown by the commercial landing figures and suggested that these two zones are the best regions for the fishery. He also pointed out that the fishery always commences with the appearance of the spawners which enter the coastal waters for spawning only and the stimulus for spawning activity is given by the lowered temperature salinity conditions, especially the former, during the monsoon months. With the return of higher values of temperature and salinity during the post-monsoon months, the spawners leave the fishing grounds and the composition of the fishery also changes during this time. The immature and juvenile oil sardines enter the coastal waters when the temperature and salinity vary from 27-28°C and 34-35 parts per thousand respectively mainly to feed on immense quantities of phytoplankton produced during these months. The juveniles practically dominate the fishery from November to January which represent the peak period and they disappear from the coastal waters by February or March when stray shoals of spent individuals appear in the fishery which usually terminates by March or April.

Sekharan and Dhulkhed (1963) found that the catches of oil sardines in the Mangalore waters consist mainly of mature fish more than two-year-old, during the monsoon months extending from July to September or October when surface temperature and salinity are low. They are scarcely seen during the next two months but reappear from December or January on-

wards. During October to March which is a period of intermediate values of salinity and temperature, the fishery is supported mainly by the one-year-old oil sardines. The older age groups occur in increasing numbers from February onwards and even form the dominant group after March during certain seasons. The catches decline after March with the increase in salinity and temperature of the coastal waters.

Murty (1965) studied the surface mixed layer and thermocline of the west coast and stated that the clue to the seasonal and regional distributions of the pelagic fisheries is to be found partly, if not wholly, in the variations in the pattern of the coastal currents. He pointed out that the catches are maximum during the winter season when the northerly drift gets established along the west coast and that the pelagic fisheries are intimately related to these coastal drifts.

Annual Variation

The annual fluctuations encountered in the oil sardine fishery has been observed from very early times and Day, as early as 1865, observed that the oil sardine is very capricious as to its arrival and departure and later Day (1889) stated that the oil sardines are abundant in some years and they occasionally forsake their haunts to return again in enormous quantities. Early records relating to the oil sardine landings are not available; however, data pertaining to the export of sardine oil, sardines used as manure in plantations, cured in the fish curing yards and used for the manufacture of oil and guano given by Nair and Chidambaram (1951) serve to give an idea of the extreme annual fluctuations seen in the fishery.

Table 1 shows the quantities of sardine oil exported from the port of Cochin which was the chief exporting centre of the Malabar coast. The fishery was poor during the seasons 1855-56, 1856-57 and from 1860-61 to 1862-63 and exceptionally good during the seasons 1857-58 to 1859-60 and 1863-64.

Table 1 — Export of Sardine Oil from Cochin Port*

Year	Qty. (in tonnes)
1855-56	2.35
1856-57	9.41
1857-58	3,579.39
1858-59	5,378.19
1859-60	6,957.23
1860-61	...
1861-62	...
1862-63	6.01
1863-64	7,744.32

*Day, 1865

Table 2 gives the quantities of fresh and sun-dried oil sardines used in coffee plantations and collected by agents of Arbuthnot & Co. Ltd., and it is evident that the oil sardine fishery was good during the seasons 1893-94 to 1895-96.

The quantities of oil sardines cured in the fish curing yards of South Kanara and Malabar between 1896 and 1907 are given in Table 3. It is seen that the oil sardine fishery was more or less uniformly good throughout the period except during 1898 to 1900 which were considered poor years for the oil sardine fishery.

Data relating to oil sardine landings for the next two decades are not available. However, the figures relating to the production of sardine oil and guano will serve to give an approximate idea of the nature of the fishery during this time. Table 4 gives the production of sardine oil and guano on the west coast and it is apparent that the oil sardine fishery was a failure during the period extending from 1908-09 to 1911-12 and from 1914-15 to 1918-19 seasons. The fishery was exceptionally good during the 1922-23 and

Table 2 — Oil Sardines Used in Coffee Plantations*

Seasons	Fresh (in tonnes)	Sun-dried (in tonnes)
1890-91	172.44	35.53
1891-92	78.38	87.79
1892-93	165.12	151.54
1893-94	206.93	1,508.05
1894-95	43.89	1,843.52
1895-96	173.48	1,698.25
1896-97	18.81	...
1897-98	25.08	...

*Thurston, 1900

Table 3 — Oil Sardines Cured in the Fish Curing Yards*

Year	Qty. (in tonnes)
1896	14,455.48
1897	9,467.25
1898	1,071.28
1899	Negligible
1900	2,160.32
1901	5,120.51
1902	8,202.37
1903	6,910.95
1904	4,971.58
1905	4,705.84
1906	5,533.65
1907	10,444.09

*Hornell, 1910

Table 4 — Production of Sardine Oil and Guano in S. Kanara and Malabar*

Seasons	Sardine oil (in tonnes)	Guano (in tonnes)
1906-07	...	5,979.93
1907-08	...	14,004.49
1908-09	...	...
1909-10	...	...
1910-11	...	196.47
1911-12	...	279.04
1912-13	...	1,956.39
1913-14	1,579.11	4,939.04
1914-15	...	...
1915-16	0.52	2.61
1916-17	...	...
1917-18	...	...
1918-19	...	...
1919-20	...	2,508.19
1920-21	...	1,567.62
1921-22	...	1,045.08
1922-23	12,540.93	33,442.48
1923-24	7,576.81	23,514.25
1924-25	2,019.16	4,180.31
1925-26	5,204.49	10,294.01
1926-27	668.85	2,194.66
1927-28	209.02	888.32
1928-29	73.16	1,261.56
1929-30	25.08	233.05
1930-31	67.93	164.08
1931-32	13.59	146.31
1932-33	0.56	20.90
1933-34	2,424.58	10,450.78
1934-35	...	...
1935-36	6.79	26.13
1936-37	469.24	2,335.75
1937-38	435.80	1,635.55
1938-39	38.15	284.26
1939-40	102.42	423.26
1940-41	471.33	2,148.68
1941-42	18.81	101.37
1942-43	5.23	54.34
1943-44	20.38	25.08
1944-45	11.12	20.38
1945-46	0.04	16.72
1946-47	...	33.44
1947-48	...	...
1948-49	...	...

*Nair & Chidambaram, 1951

1923-24 seasons when the total production of oil and guano along the co reached the colossal figures of 20,000 tonnes and 57,000 tonnes respective The magnitude of the catches during these two seasons alone will beco apparent from the fact that about 2,85,000 tonnes of oil sardines have be utilized for the production of guano alone excluding the quantities consum in the fresh condition, used for curing and utilized for the production beach manure. These figures also serve to give an idea of the magnitude the shoals of oil sardines which were frequenting the inshore waters duri the years of abundance.

The estimated landings of oil sardine compiled by different fish curing ya of South Kanara and Malabar and by the Central Marine Fisheries Resea Institute for the west coast of India are given in Tables 5 and 6 which sh

Table 5 — Landings of Oil Sardine in S. Kanara and Malabar*

Seasons	Qty. (in tonnes)
1925-26	44,507.2
1926-27	14,804.5
1927-28	7,204.0
1928-29	1,807.7
1929-30	2,757.7
1930-31	4,324.8
1931-32	2,185.4
1932-33	1,123.9
1933-34	71,796.5
1934-35	20,834.7
1935-36	1,498.5
1936-37	27,161.7
1937-38	17,021.2
1938-39	3,413.2
1939-40	7,090.2
1940-41	25,268.8
1941-42	4,450.2
1942-43	919.5
1943-44	442.5
1944-45	656.7
1945-46	17.7
1946-47	8.8
1947-48	1,191.1
1948-49	290.7
1949-50	3,390.0

*Nair & Chidambaram, 1951

clearly the characteristic annual fluctuations seen in the fishery during the last four decades. The best catch was recorded in 1968 when glut conditions reminiscent of the former years of abundance were seen and the fish contributed about 33 per cent of the country's total marine fish production for that year. It is seen that the annual catch of oil sardine varied considerably during these years and the fishery reached disastrously low levels during the forties and the lowest catch of 8.8 tonnes was recorded during the 1946-47 season. The fishery showed a remarkable recovery, especially during the last one decade when the catches exceeded 1,00,000 tonnes most of the years.

The fluctuations in the oil sardine fishery have been attributed to be due to various causes by the earlier workers, and Day (1865) thought "it must be left for future years to demonstrate whether the present increase of the fish oil trade is a healthy or unhealthy stimulus due to the present high prices; for if the latter, the fisheries are being overworked and the future loss will be great. The extreme violence of the south-west monsoon of course protects the fish from the commencement of June until September, but the period of the year at which the various species spawn, more extended observation on their arrival and departure and a thorough examination into the fish that is captured as to whether the young are or are not used for salting or for fish oil, are objects which it would be very important to ascertain". Thurston (1900)

Table 6 — Estimated All-India Production of Oil Sardine*

Year	Qty. (in tonnes)
1950	34,420
1951	17,240
1952	13,896
1953	51,831
1954	33,954
1955	30,447
1956	7,412
1957	1,91,469
1958	1,23,731
1959	69,234
1960	1,89,016
1961	1,67,884
1962	1,10,229
1963	63,647
1964	2,74,333
1965	2,61,863
1966	2,47,214
1967	2,56,324
1968	3,01,446

*Nair, 1960; CMFRI, 1969

and Nicholson (1915), who discussed the fluctuations in the oil sardine fishery, have not suggested any cause for the same.

Hornell (1910) who discussed the occasional disappearance of the oil sardines from the inshore fishing grounds for several consecutive years suggested the necessity for a sound knowledge of the factors controlling and influencing the migrations and thought that these are influenced by causes more powerful than those responsible for the annual migration. It was suggested that the disappearance of the sardine shoals during consecutive years may be due to combination of certain unfavourable conditions in the inshore waters resulting in the low production of diatoms which normally attract the shoals to the inshore waters. He stressed that this factor may be of supreme importance since the fishermen believe that there exists a relation between rainfall and the abundance or otherwise of oil sardines.

Sundara Raj (1934, 1937) thought that the capture of large numbers of immature sardines is likely to affect the fishery adversely.

Devanesan (1943), and Devanesan and Chidambaram (1948) suggested respectively overfishing and the intrusion of an immature generation in the fishery as probable causes of the fluctuation.

Chidambaram (1950) while discussing the environmental factors responsible for the fluctuations in the fishery, suggested that temperature, salinity and availability of food control the spawning and survival of the larvae and fry.

Nair (1953b) after a detailed study of the food and feeding habits of the oil sardine extending over a few years concluded that the availability of *Fragilaria oceanica*, which is the most favourite food of the juveniles, is one of the major factors governing the fluctuations in the oil sardine fishery. According to him, optimum temperature-salinity conditions and the availability of *Fragilaria oceanica* are the causative factors which influence the movements of the juveniles on the abundance of which depends the success or failure of the fishery every year.

Sekharan (1962) and Sekharan and Dhulkhed (1963) are of the view that the catch fluctuations appear to be related mainly to fluctuations in the year class strength. Banerji (1967) found no relation between abundance and fishing effort and stated that fishing success is not due to fishing but is brought about by fishery-independent factors. According to him, the major portion of the catch comes from the 0-year class and the fluctuation in the catch varies with those of this year class. He pointed out that it is necessary to search for fishery-independent factors which cause such fluctuations in yearly recruits.

Recently, Sam Bennet (1968) stated that the fluctuations in the annual catch of the Indian oil sardine are related to those of the strength of the new year class recruited into the fishery. According to him, an exceptionally strong recruit class may vitally affect the strength of the recruit class of the subsequent year. He is of the opinion that an analysis of the year class composition of the commercial catches and a knowledge of the strength of the recruit class may help in predicting the fishing success for the subsequent one or two years.

Legislation

The unprecedented failure of the oil sardine fishery extending over a number of years during the forties and its disastrous effects on the industries which it supported during the years of plenitude received the attention of the Government of Madras and a legislation to prevent the capture of the juveniles and the spawners was introduced in 1943. The main clauses of this legislation were the prohibition of: (i) the use of the highly destructive boat-seine (*Mathikolli vala*) during the sardine season from August to April, (ii) the use of the gill-net (*Mathichala vala*) during the spawning period during August and September, and (iii) the landing of oil sardine below 15 cm. exceeding a total weight of one maund (37 kg.) from any single boat during the fishing season. The legislation was modified and extended for two more years from 1945 to prohibit the use of these two nets throughout the season and the landing of immature sardines. The legislation, however, lapsed in 1947 and was not extended further owing to some practical difficulties encountered in the enforcement of the details of the regulation amongst which were the lack of preventive staff over a long coastline and absence of similar legislation in the adjoining States.

Bionomics

Sex Determination

George (1959) pointed out an easy and quick method to distinguish the sexes of the oil sardine in the field without dissection. According to him there is an externally visible muscular papilla in the cloaca of the male oil sardine and a membranous papilla behind the anal opening of the female oil sardine. It has also been shown that the structure of the external genitalia of the oil sardine is useful in distinguishing the spent and recovering condition of the fish. In the spent recovering fish the muscular papilla in the male and the membranous papilla in the female are very prominently seen inside a widely gaping cloaca, while in specimens maturing for the first time these are less conspicuous and are inside a more or less closed cloacal chamber.

Age and Size at Maturity

While discussing the spawning habits and migration of the oil sardine, Hornell (1910) stated that the shoals of fish arriving by the end of June consist entirely of mature sardines with well developed gonads and that they are seen till the end of August after which the shoals consist of spent individuals. It was also stated that the sardines after spawning rapidly grow fat and in September these fat laden sardines are caught in enormous quantities during the peak period extending from October to December.

According to Hornell and Nayudu (1924) oil sardines attain sexual maturity at almost full adult size at the age of one year when they measure on an average 15 cm. in standard length. Hornell and Nayudu did not collect oil sardines in the oozing condition during the course of their investigation.

Active spawners of oil sardine in the oozing condition were collected b Devanesan (1943). The measurements of the oil sardines in the sample whic contained the active spawners ranged from 15 to 17.4 cm. and he believe that sexual maturity is attained for the first time when the sardines reach length of 15 cm., the sizes below this being immature. Chidambaram an Venkataraman (1946) also state that the oil sardine attains a size of 15 cm. a first maturity.

Nair's (1953b) study showed that active spawners are generally found i the three-year-old sardines measuring 17 cm. and above in total length According to him oil sardine spawns only once in their lifetime as shown b the almost simultaneous maturation and extrusion of all the mature eggs an also by the scarcity of partly spent and recovered spent oil sardines. Nai (1959) also pointed out that Hornell and Nayudu's estimation of the firs year's growth of 15 cm. when maturity is attained is very high since the believed that the juvenile stock observed by them in the fishery during thei investigation to be the recruits of the same spawning season. He also con

Fig. 2 — Ovary of oil sardine in stage VI (x c. 1.3)

firmed his earlier conclusions relating to the age and size at maturity by a detailed study of the oil sardine and its fishery during the subsequent seasons as well.

According to Dhulkhed (1964) the minimum size at first maturity is 16.5 to 16.9 cm. and the eggs are released by the spawners in a number of successive batches. Prabhu (1967) collected large oil sardines with rematuring gonads during November and December and stated that the present belief that the sardines spawn only once may have to be revised. Radhakrishnan (1965) found the minimum size at first maturity around 12 to 13.9 cm. and suggestec the possibility of individual fishes entering the spawning season more thar once during their lifetime.

Fecundity

Devanesan and Chidambaram (1943) estimated that a ripe female oil sardine produces on an average over 70,000 eggs. Nair and Chidambaram (1951) stated that the fish is a prolific breeder judging from the production of 75,000 eggs. Nair (1959) studied the fecundity of oil sardine using ovaries in maturity stage VI (Fig. 2) and stated that the left ovary is generally larger than the right and produces more eggs, namely 40,000 eggs while the right ovary produces only 38,000 eggs. He also pointed out that fecundity is directly proportional to the weight of the ovary which in turn is generally related to the size of the fish.

Spawning Season

According to Hornell (1910) the spawning season is one of considerable duration extending from the end of June to the end of August. He also believed that the spawning is a little earlier in the north than in the south since the shoals of mature oil sardines arrive off the South Kanara coast much earlier than in the Kozhikode and Cochin coasts. Later, Hornell and Nayudu (1924) stated that the spawning period extends from the end of May to the end of August with maximum spawning taking place during June and July.

Devanesan (1943) collected active spawners and planktonic eggs during September and October and doubted the accuracy of Hornell and Nayudu's conclusion that intensive spawning is limited to June and July since these authors have not explained the occurrence of a good percentage of males and females with large gonads in September and October.

Nair (1953b, 1959) pointed out that the south-west monsoon is an important factor influencing the entry of spawners into the coastal waters and consequently the spawning season shows a tendency to shift depending on the early or late onset of the monsoon. This observation is corroborated by the differential rate of growth during the first year. The spawners enter the coastal waters after the commencement of the monsoon generally during June and July. The gonadial maturity of the spawners ranges from stage V to VI in the different shoals of mature sardines seen in the fishing grounds at this time. Intensive spawning generally takes place during August and September.

Hornell (1910) and Hornell and Nayudu (1924) believed that the shoreward migration of the adult oil sardines is to feed upon the immense quantities of microplankton produced towards the close of the south-west monsoon.

The food and feeding habits of the juveniles, adult spawners and spent oil sardines have been studied in sufficient detail (Nair, 1953b) and it is found that active spawners always show an empty stomach indicating the cessation of feeding activity at the time of spawning. The shoreward migration of the spawners is believed to be for spawning purposes and the stimulus for this is given by the outbreak of the monsoon which alters the temperature-salinity conditions appreciably.

Spawning usually takes place at night and Devanesan and Chidambaram (1943) believed that the fish spawns a few days before and after the new moon day. The actual spawning grounds of the oil sardine have not so far been located since the adverse weather conditions and the roughness of the sea during the monsoon months make it almost impossible to undertake field trips with the existing facilities. Nevertheless judging from the relative scarcity of the planktonic eggs (Fig. 3) in the fishing grounds of the oil sardine it is presumed that the main spawning grounds are located beyond the present fishing zone (Nair, 1959).

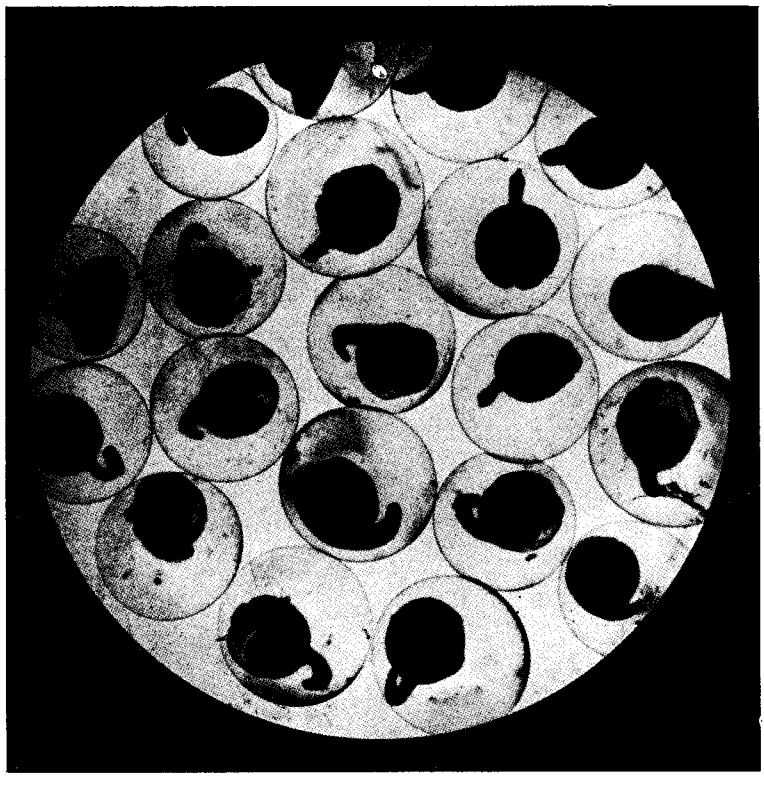


Fig. 3 — Photomicrograph of eggs of oil sardine collected from plankton (x *c.* 14)

instances three oil globules have also been noticed in the eggs. The embryonic development is very rapid and is usually completed within 24 hours. Nair (1959) gave a detailed descriptive account of four successive stages in the embryonic development of the oil sardine (Fig. 4).

Newly Hatched Larva—The newly hatched larva (Fig. 5) floats on the surface of the water owing to the buoyancy of the yolk and the oil globule and measures 2.75 mm. in average length. The yolk is ellipsoidal and extends nearly two-fifth the length of the larva. The oil globule generally occupies a central position near the ventral periphery of the yolk mass. The myotomes are distinct and their muscle fibres show the characteristic crossed arrangement seen in clupeoid larvae. The pigmentation of the newly hatched larva is very feeble and is confined to the dorsal side in the form of scattered, unbranched black pigment cells which are arranged closely in the anterior region and sparsely in the posterior region (Nair, 1959).

One-day-old Larva—The one-day-old larva (Fig. 6) measures 3.35 mm. in average length and shows considerable reduction in the size of the yolk mass, the segmentation of which is seen somewhat faintly in this stage. The oil globule disappears in the one-day-old larva. The auditory vesicle is large and the developing pectoral fin is seen as a flap-like structure behind the auditory vesicle. The lower jaw appears as a bud-like projection in this stage. The origin of the dorsal finfold has shifted anteriorly and it is opposite the base of the pectoral fin. The black chromatophores present on the dorsal side of the newly hatched larva have become larger and stellate and begun to migrate to the ventral side. This migration of the chromatophores commences from the posterior end where a linear group of highly branching black chromatophores is present on the ventral side of the postanal region. The actual process of vertical orientation of the chromatophores is seen in the middle portion of the larva where several such pigment cells are present on

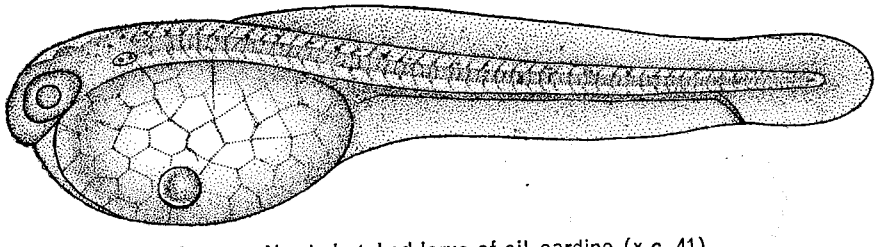


Fig. 5 — Newly hatched larva of oil sardine (x c. 41)

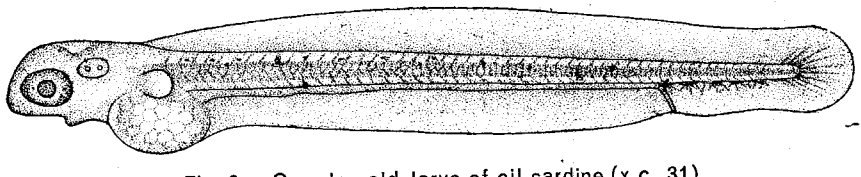


Fig. 6 — One-day-old larva of oil sardine (x c. 31)

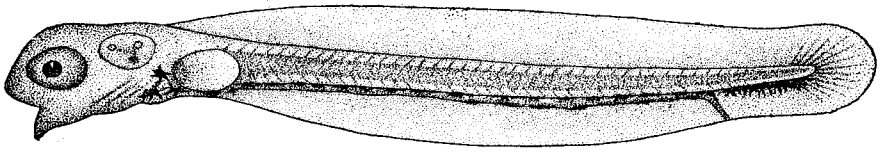


Fig. 7 — Two-day-old larva of oil sardine (x c. 31)

the lateral sides of the myotomes. The eyes are golden yellow in colour and a few irregularly arranged yellow pigment cells are present in the caudal region.

Two-day-old Larva—The two-day-old larvae (Fig. 7) are very active and the slightest disturbance makes them dart from place to place in a serpentine manner. They are longer than the previous stage and measure 3.7 mm. in average length. The yolk is completely absorbed and the mouth is well developed in this stage. The auditory vesicles and the pectoral fins have become larger in size. The alimentary canal shows a slight widening of its posterior half. The basic pigmentation of the larva gets stabilized and all the pigment cells present on the dorsal side of the newly hatched larva have migrated to the ventral side. The postanal pigmentation is very conspicuous owing to the accumulation of highly dendritic black chromatophores. A few large stellate black pigment cells are present in the region of the heart. The pigmentation of the alimentary canal is characteristic and the chromatophores are arranged on the dorsal side throughout its entire length while similar chromatophores found on the ventral side are confined to the posterior half of the alimentary canal. The colouration of the eye resembles that of the adult in having a silvery white colour and shine.

Three-day-old Larva—The three-day-old larva does not show any significant change from the previous stage except in the reduction in the length which is a normal feature seen after the complete absorption of the yolk mass.

Adult

Growth and Longevity—Hornell and Nayudu (1924) made a detailed study of the oil sardines in the commercial catches during the period December 1921 to December 1922. They traced the growth of the oil sardine from the earliest stage met with in the fishery until sexual maturity is attained and also traced the later history of the oil sardine which spawned for the first time. For this study they observed three successive generations of oil sardines in the fishery and estimated their growth rate and age by the majority size method and also by the growth markings in the form of rings on the scales. They noticed that the growth check coincided with the period of arrested growth caused by the decrease of food organisms in the inshore waters from January to April. A second ring was also observed by them in the scales of a few specimens of large oil sardines which generally survive in small numbers. Based on these studies Hornell and Nayudu concluded that oil sardines attain

a size of 15 cm. standard length at the age of one year, and growth during the second year is extremely slow and amounts to only 1 cm. in length. The oldest sardines examined by them were approximately 2½ years old which was believed to be the ordinary limit of life of the oil sardine. Nair (1959) pointed out that these authors have considered the two juvenile generations measuring 13 and 10.5 cm. in modal size found in December 1921 and December 1922 respectively to be the recruits of the spawning seasons of the respective years and consequently a high rate of growth is estimated by them during the first year. However, they made the significant observation that not more than three generations of oil sardines can be found at any time and that too between August and December only every year.

In the course of a detailed study of the scales of the oil sardine, Devanesan (1943) noted the first growth ring in fish measuring 6.5 cm., six rings in sardines measuring 8.7 cm. and stated that nine or fourteen rings may be expected to be present in fishes of 15 and 18 cm. size groups respectively. He suggested that the life-span of the oil sardine extends over fourteen years.

In view of the contradictory opinions on the age of the oil sardine based on the study of the scales, Nair (1949) made a detailed study of the otoliths of the oil sardine and detected two and in exceptional cases three growth rings. He came to the conclusion that the average life-span of the oil sardine is about three to four years.

Chidambaram (1950) studied the length frequencies, size and age groups of the oil sardine for a few years and his findings lend support to Nair's conclusions. He also inferred that the oil sardine's life-span is between three and four years, and estimated the average length of the oil sardine as 10, 14.5, 18.3 and 20.5 cm. at the end of the first, second, third and fourth year respectively.

Nair (1953 b), based on the averages of the modes in the length frequency data collected for a few years, stated that the new stock recruited every year during the short spawning season grows to a size of 10 cm. and enters the fishery in a very immature condition during the subsequent year. At the end of the second year when the gonads are in the early stages of maturity the fish measures 15 cm. They attain the adult spawning size of 19 cm. at the end of the third year. A small percentage of the oil sardine population alone reaches the maximum size of 21 cm. and above during the fourth year. At the same time, he stressed the fact that the rate of growth in the different year classes varies owing to the slight shifting of the time of recruitment and also by the fluctuations in the availability of the favourite food of the larval and juvenile sardines.

According to Chacko (1955) the oil sardine fishery commences in July with spawners measuring 18-20 cm. In September young ones contribute to the fishery and during the peak period from November to January juveniles constitute the catches. In May and June adults measuring 15 to 17 cm. with maturing gonads form the shoals. Chacko and Mathew (1956 b) stated that recruitment of new broods measuring 5 to 8 cm. takes place in September and

these continue to grow and contribute to commercial catches till the end of the year. According to them, the size progression is 9 to 11 cm. in October, 11 to 14 cm. in November, 12 to 15 cm. in December and January and 13 to 16 cm. in February and March.

Balan (1959) studied the scales of oil sardine and found that a ring usually appears as a semicircular mark concentric with the scale margin and breaks the continuity of the circuli. False rings were also noticed by him in some scales. Based on this study he found that scales with one, two and three rings make their appearance when the oil sardine measures 9 to 9.9, 12 to 12.9 and 15 to 15.9 cm. respectively. The one ring class dominates up to 16 to 16.9 cm. size group and the two ring class in the higher size groups while the three ring class was encountered in small numbers only. He found that the period of ring formation is between May and July and that only one ring is formed every year. He also studied the length frequency distribution along with the scale studies and found that there is fair agreement in the age and rate of growth determined by these two methods. The age and rate of growth of the oil sardine have been further studied by Balan (1964) by examining the relationship between the lengths of the fish and the scale. The back-calculated lengths of the oil sardine indicate that the fish attains the average length of 14.3, 16.4 and 18.4 cm. at the end of one, two and three years respectively.

Bensam (1964 d) holds the view that the juveniles recruited into the fishery in a given year are the offspring of the same year's spawning and that they re-enter the fishery having become mature and spawn for the first time in the succeeding year when they complete one year with a modal length of 14.5 to 15.5 cm. By the end of the second year the fish attains a modal length of 17.5 cm. and spawns for a second time. According to him some specimens enter the third year of life with an increase of 1 cm. in modal length.

According to Prabhu and Dhulkhed (1967) the size at which the one-year-old sardines enter the fishery during the commencement of the season in July is about 10 cm. and they categorically state that this group does not belong to the same year's spawning but is the product of the previous year's spawning. They consider the modes around 10 cm. seen from July to October of different years to be the products of late spawning of the previous years. Prabhu (1968) in a rejoinder to Dutt's (1968) criticism states that the progeny spawned at different periods may have different rates of growth in view of the significant environmental variations recognized during the monsoon, pre-monsoon and post-monsoon periods.

Radhakrishnan (1965) holds the view that the modal size of the one-year-old oil sardine ranges from 13.5 to 14.5 cm. and that during the second year it varies from 16 to 16.5 cm. The growth rate is fast in its earlier stages of life and the growth slows down considerably when the fish enters the second year of life.

Length-Weight Relationship—The length-weight and volume relationships of the oil sardine have been studied by Dhulkhed (1963) by using the logarithmic formula $\log W$ or $\log V = a + b \log L$; where W = weight;

V = volume; L = Length; a = constant and b = exponent. The length-weight and length-volume equations are as follows:

	Length-weight	Length-volume
Indeterminate	$\bar{7}.6451+3.6169$ log L	$\bar{7}.6599+3.5940$ log L
Female	$\bar{6}.3420+3.2665$ log L	$\bar{6}.4108+3.2320$ log L
Male	$\bar{6}.7010+3.1086$ log L	$\bar{6}.6944+3.1091$ log L
Combined	$\bar{6}.4662+3.2123$ log L	$\bar{6}.3489+3.2623$ log L

The differences between regression coefficients were tested for significance by the 't' test and were found to be non-significant.

Food and Feeding Habits—A preliminary study of the food and feeding habits of the oil sardine was made by Hornell (1910) and he found that the fish generally feeds on the flocculent muddy scum found at the sea bottom during October to December. This mud was mainly composed of unrecognizable matter in the form of a smooth homogeneous greenish or greenish grey mud mixed with large quantities of many species of diatoms. He, therefore, concluded that the sardines feed by browsing upon the flocculent muddy scum at the bottom of the sea. Later, Hornell and Nayudu (1924) also noticed that the food of the oil sardines consisted of unrecognizable matter in the form of fine greenish and brownish green mud which formed as much as 90 per cent of the volume of food taken by the oil sardine. The recognizable matter which they observed consisted of diatoms during May to August, dinoflagellates during September to November and miscellaneous forms during December to April. The presence of high proportion of mud in the food led them to believe that the oil sardines show a general preference for bottom feeding.

Devanesan (1943) also noticed the presence of such unrecognizable matter in large quantities in the stomach contents of the oil sardines, but his examination showed that this matter is composed only of diatoms and other planktonic elements well digested in the stomach rendering their identification difficult and giving the appearance of fine mud. He inferred that the oil sardine is a surface feeder, occasionally resorting to bottom feeding when conditions are not favourable at the surface. Oil sardines from Bombay-Karachi zone examined by him, however, showed large quantities of sand grains mixed up with their food and he believed that the oil sardines of this zone are a separate race showing bottom feeding habits in contrast to the surface feeding habits of the Malabar oil sardines.

Devanesan (1942) 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 Menon (1942) never observed any fish eggs in the stomach contents of the oil sardines of the Trivandrum coast and they pointed out that the oil sardines are essentially phytoplankton feeders.

A detailed study of the food and feeding habits of the oil sardine extending over a few years was made by Nair (1953 b) and according to him phytoplankton is the chief food of the juvenile and adult oil sardines. Among the different diatoms found in the dietary of the oil sardine, *Fragilaria oceanica* Cleve

forms the most important constituent and he found the existence of a significant correlation between the occurrence of this diatom and the oil sardine. The major peak in the occurrence of this diatom is in June and July representing the monsoon months and a secondary peak is reached during September and October more or less coinciding with the peak period of the oil sardine fishery. Later, Nair and Subrahmanyan (1955) pointed out the correlation between the diatom and the oil sardine and stated that the peak of the oil sardine fishery when the juveniles dominate the catches is reached during or immediately after the bloom of *F. oceanica*. They suggested the possibility of using the diatom as an indicator of abundance of the oil sardine in the coastal waters.

Kuthalingam (1960) studied the food and feeding habits of post-larval and adult *S. longiceps* of Madras coast. The dominant food items found in the stomachs of the adult fish were small-sized crustaceans like copepods, ostracods, *Lucifer* and larval prawns. Other items found in the stomachs were larval bivalves, polychaete larvae, sergestids and a few diatoms and algae. According to him the food of post-larval *S. longiceps* consisted mostly of diatoms and algae.

Dhulkhed (1962) studied the food and feeding habits of the oil sardines of Mangalore zone and found that *F. oceanica* formed one of the most important items in the diet of the fish. He found that good catches of oil sardines were made when phytoplankton was present throughout the year while the yield of the fish declined when the phytoplankton was comparatively poor.

Kagwade (1964) also found that the oil sardine is a predominantly phytoplankton feeder with diatoms, dinoflagellates and zooplankton appearing in the order of abundance in its food, *F. oceanica* being an important item all round the year. The blue-green algae, *Trichodesmium thiebautii* Gomont was frequently met with in the food of the oil sardine. Chacko and Mathew (1956 b) also observed that *Trichodesmium* is consumed by the oil sardine in fair quantities during the months February and March. Very often Kagwade (1964) found the bulk of the stomach contents to be composed of unrecognizable detritus. According to her observation there is a certain amount of selectivity in the nature of the food consumed by the oil sardine.

Bensam (1964 c) found that the juvenile oil sardines feed mainly on a carcinivorous diet while the adults feed mostly on phytoplankton. The gill-rakers are either imperfectly developed or underdeveloped in the case of the juveniles while in the adults they are fully formed. He pointed out 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 adult is due to their efficient sieving of the minute organisms. He stated that the juveniles are chiefly predators on planktonic crustaceans and the adults feed mostly on phytoplankton. He is of the opinion that the pharyngeal pockets assist in concentrating the minute food organisms ingested by the gill-rakers.

The oil sardines occurring in the Karwar zone were found to feed

exclusively on plankton with the diatoms forming an important item of food (Noble, 1965). They were abundant in the food of the oil sardine during the months July to September and December to February. Copepods were also found to be equally important during the other months when they dominated in the food of the oil sardine.

Shoaling Behaviour

Behaviour studies of pelagic fishes are helpful for a proper understanding of the dynamics of fish population and also in practical fishing operations. Investigations carried out in other countries have given interesting results and no attempt has been made till now for studying the shoaling behaviour of Indian fishes. Balan (1961) made some interesting observations on the shoaling behaviour of the oil sardine. According to him a shoal means a dense or loose concentration of fish at the surface or sub-surface and the various actions of the fish in the shoal under natural conditions, both individually and collectively are considered as shoaling behaviour.

Surface Shoals

Flipping Shoals—An interesting feature of the flipping shoals is the occurrence of frequent splashing noises and jerking movements of the oil sardine in the surface waters. Flipping shoals occur during day and night and they are more frequent during morning and night. The cause of the flipping action of the individuals in the shoal is not known; however, it is considered probable that the flipping action gives more momentum in the movement of the fish.

Pattering Shoals—Pattering is characterized by frequent noises either simultaneous or in quick succession resembling the sound of big rain drops falling on water. Pattering shoals are frequently seen during the day than during the night. It is probably an action to attract more sardines for dense aggregation.

Rippling Shoals—A distinguishing feature of the surface moving shoals is the formation of ripples which could be seen even under strong windy conditions. Some of the individual fishes of the rippling shoals are visible even from a distance. Sometimes rippling shoals move in different directions and such shoals are easily caught by fishermen. Small rippling shoals may attract and merge with similar ones occurring in the vicinity and form larger shoals. Heavy rippling is produced by shoals composed of large and mature sardines.

Leaping Shoals—Occasionally some of the oil sardines in the shoals leap above the water covering short distances. Besides this normal leaping shown by the sardines in a leaping shoal, it is also done as a means of escape when pursued by predators or frightened by the fishing operations.

Bluish Coloured Shoals—Apart from the shoals exhibiting characteristic features in the behaviour pattern, it is possible to distinguish other shoals by the colour effects associated with them. Shoals exhibiting a bluish colour are encountered in appreciable numbers during the peak period of the fishery. This colouration is a feature of slow moving compact shoals observed during

daytime. The individual fishes are not distinguishable; however, the shoals are easily caught by fishermen. It is likely that this colour effect is caused by the incidence of sunlight on the shoals.

Pinkish Coloured Shoals—Very often large shoals of oil sardines show a pinkish tint during daytime. The individual fishes in these slow-moving shoals are not visible and heavy catches are usually made from such shoals. The fishermen are of the view that this colouration is caused when the shoals disturb and scatter the bottom mud.

Luminescent Shoals—A luminescent shoal appears as a patch of light moving at the surface. The luminescence of the shoals is useful for spotting the shoals during the dark phase of the moon. The oil sardines are easily caught when the luminescence is moderate while bright luminescence is considered unfavourable for fishing since the light enables the fish to see and avoid the nets.

Bottom Shoals

Bubbling Shoals—The presence of bottom shoals is often judged by the fishermen by the chain of tiny air-bubbles which emerge from the sea bottom and break up at the surface. It is considered likely that these bubbles are released from the air-bladder. The fishermen often look for this sign while searching for a bottom shoal and according to them these bubbles are released by the sardines from the muddy bottom while feeding in the region.

Fishy Odoured Shoals—Sometimes a strong fishy odour emanates from the fishing grounds indicating the presence of sardine concentration at the bottom and fishermen usually make heavy catches from such shoals. This fishy odour is probably caused by the discharge of mucus from large concentrations of oil sardines.

Size and Shape of Shoals

An approximate visual estimation of the size of the various shoals encountered was made by Balan (1961) and according to him the shoals varied from 2 to 25 m. in length and 1 to 20 m. in breadth. The size and shape of the surface swimming shoals have been studied and it was found that the front region of the shoal is usually narrow and slightly pointed while the hind end is blunt. It would appear that a few fish in the front portion of the shoal lead the rest in surface shoals, especially the rippling shoals. The pattering shoals were observed to be more or less oblong in shape while the bluish shoals appear somewhat narrow and long with indistinguishable boundaries.

Movement of Shoals

The speed of individual shoals of oil sardines has not been studied with any degree of accuracy and rough estimates show that small shoals of sardines swimming at the surface are generally quicker in their movements and certain surface shoals move at the rate of 5 km./hr. The speed of the bluish and pinkish coloured shoals is considerably lower than that of the rippling shoals. A large number of shoals come to the surface at sunset.

Length Composition of Shoals

Balan (1961) who carried out this work for about a year studied the sample taken from the different shoals and he found that the average and moda lengths of the fish were near each other in all the samples indicating that oi sardines belonging to the same size and age groups tend to shoal togethe while a small percentage only was contributed by larger fishes belonging t the other age groups. Prabhu and Dhulkhed (1967) also observed that th juvenile population is composed of more than one group, but there is n intermingling of the different groups as shown by the unimodal nature o the size frequencies.

Population

Sex Ratio—According to Hornell and Nayudu (1924) the females prepon derate among the juveniles till they become mature and move off to the spawn ing grounds. They also observed that the percentage of the females is i excess of that of the males among the spawners also. On the other hand, the found that the males predominated slightly over the females in the case of th spent sardines and this was attributed by them to a considerably higher rat of mortality of the females after spawning than males.

Chidambaram (1950) noticed equal proportion of the sexes in the oil sar dines measuring less than 20 cm. while the females predominated in the fishe measuring above this size.

Nair (1959) observed that there is considerable agreement in the propor tion of the sexes in different age categories especially among the juveniles an the spawners. He also pointed out that the relative scarcity of the spent an recovering oil sardines and the negligible numbers of the four-year-ol sardines encountered in the fishery indicate that the mortality is very hig among both the sexes after spawning.

Radhakrishnan (1965) found that the males are relatively more numerou among the immature group while the females outnumbered the males amon the spent oil sardines.

Age Composition—Different age classes which were found in the fisher during the seasons 1936-37 to 1942-43 were studied by Chidambaram (1950) The sizes of different age classes at their first appearance in the fishery an their subsequent yearly growth rate estimated by him are given in Table 7.

Table 7 – Maximum Sizes (cm.) of the Year Classes of Oil Sardine in Different Seasons*

	1936-37	1937-38	1938-39	1939-40	1940-41	1941-42	1942-43
1st year	...	...	9.0	9.0	12.0	10.0	10.0
2nd year	...	13.0	14.0	16.0	15.0	14.0	15.0
3rd year	18.0	18.0	19.0	20.0	19.0	16.0	...
4th year	...	...	...	...	21.0	20.0	...

*Chidambaram, 1950.

Based on the study extending from 1948-49 to 1953-54, Nair (1953b, 1959) pointed out the regular cyclical changes in the age composition of the oil sardine schools encountered in the fishing grounds. He stated that the fishery always commences with the appearance of the three-year-old spawners during the south-west monsoon. The post-monsoon months show the disappearance of the spawners and the entry of the juveniles composed of the one- and two-year-old sardines which dominate to form the bulk of the commercial catches every year. The spent oil sardines generally appear during the closing stages of the fishery.

Size Composition—The changes in the size composition of the oil sardines in the commercial catches at Kozhikode have been studied continuously from 1933-34 season onwards excepting for a short break when the legislation was in force. Sundara Raj (1934-40) and Green (1940, 1941) in different administration reports give the length frequency figures of the oil sardines sampled from the commercial catches. The dominant size groups seen in the fishery of different seasons are given in Table 8.

The detailed changes in the size composition of the oil sardines in the commercial catches at Kozhikode given by Chidambaram (1950) and Nair (1953b, 1959) are given in Table 9.

The annual length frequency distribution of the oil sardines in the commercial catches during 1955-64 given by Balan (1964) is given in Table 10.

Mortality—The only instance of large-scale oil sardine mortality was observed by Hornell (1910) during a fishery cruise along the Malabar coast to the Laccadive Islands in November 1908. He observed extensive stretches of dirty ochreous yellow tinted water containing numerous dead and dying oil sardines and the mortality is believed to be caused by foul water. Plankton collections from these regions showed only obscure organic and unrecognizable fine debris which had the appearance of river filth or sewage containing scarcely any living organism.

Table 8 — Dominant Size Groups (cm.) During Different Seasons

Seasons	Dominant size groups
1933-34	13
1934-35	17
1935-36	16
1936-37	5, 12, 16, 20
1937-38	14, 17
1938-39	9, 16
1939-40	12, 18
1940-41	4, 14, 19

Table 9 — Dominant Size Classes (cm.) During 1936-37 to 1942-43* and 1948-49 to 1954-55†

Seasons	Dominant size classes
1936-37	9, 12, 16
1937-38	13, 17
1938-39	9, 16, 18
1939-40	9, 12
1940-41	4, 14, 19
1941-42	9, 15
1942-43	14, 17
1948-49	15, 19
1949-50	10, 13, 17
1950-51	9, 13, 19
1951-52	12, 16, 19
1952-53	10 - 16, 18
1953-54	9 - 11, 15-16, 18, 21-22
1954-55	5, 13-15, 17

*Chidambaram (1950) †Nair (1953b; 1959)

Table 10 — Annual Length Frequency Distribution of Oil Sardine* (cm.)

Seasons	1st year	2nd year	3rd year
1955-56	12.0	16.0	18.0
1956-57	12.0	17.0	19.0
1957-58	13.0	16.0	...
1958-59	14.0	15.0	16.5
1959-60	13.5	15.0	17.5
1960-61	14.5	16.5	17.5
1961-62	12.5	15.0	16.5
1962-63	12.5	16.5	...
1963-64	13.5	17.0	...

*Balan, 1964

Predators—Balan (1961) recorded two varieties of terns which hover around the shoals of oil sardines and pick up the fish uttering shrill noise. These terns are extremely predatory and the diving of these birds usually give an indication of the presence of oil sardine shoals. *Larus brunnicephalus* Jerdon is the common sea-gull found preying on oil sardine. The common dolphin, *Delphinus delphis* Linn. has often been found disturbing and scattering the shoals of oil sardines and oftentimes it feeds on netted oil sardines as well.

Parasites—A tetraphyllid cestode larva, *Platybothrium sardinellae* from ıe pyloric caecae and an advanced larval trematode from the pyloric caecae nd the stomach are the parasites recorded so far from the oil sardine Hornell & Nayudu, 1924). The latter parasite is found to be common uring January, March and April.

Abnormalities—An instance of hermaphroditism was recorded by Antony aja (1963) where the two gonads differed in size and shape and showed eparate ducts opening independently on the genital papilla. The right gonad vas an ovo-testis and the left one a partially spent ovary. Bensam (1964 a) ecorded other instance of deviation from the normal gonads met with in oil ardine. He collected males with vestigeal right gonad and with the gonads used anteriorly and females with the gonads fused posteriorly and with trophied right and left gonads. Dhulkhed (1965) observed the presence of wo distinct lobes in both the right and left ovary. The upper lobe was arger than the lower and the two lobes were joined together by connective issues. The oviducts from the lower lobes united to form a common duct vhich opened to the outside.

Certain morphological abnormalities have been observed by Pillai (1967) ınd they were in the form of a curvature in the region of the caudal peduncle, ıbsence of the caudal fin and the absence of the upper caudal lobe.

Bensam (1965) studied the regeneration of the caudal fin in *S. longiceps* Cuv. & Val. and found that regeneration is mostly confined to the lower caudal lobe of spawning oil sardine, which according to him is injured by some peculiarity in the behaviour of shoals in spawning.

FISHERY

Exploitation

Fishing Areas

The range of distribution of the oil sardine in the Indian waters extends from Kathiawar to the Coromandel and the Ganjam coasts. But large-scale shoaling is seen only along the South Kanara and Malabar coasts. The fishery of the oil sardine is restricted to a narrow 16 km. broad strip of the inshore waters and this is necessitated by the nature and size of the craft employed in the fishery, namely, the dug-out rowing canoe.

Fishing Craft and Gear

The dug-out canoe, as the name implies, is made from one log of wood and it varies in size with displacements ranging from 3 to 5 tonnes (Fig. 8). The largest dug-out canoe (*Odam* or *Vanchi*) is 9.8-12.8 m. in length and is used for operating the boat-seine while the smaller one (*Thoni*) measures from 8.5-9.8 m. and is generally used for gill-net and drift-net fishing in addition to boat-seine operations. The *Rampani* boat is a built-up-canoe with a

Fig. 8 — Cast-net fishing from a dug-out canoe

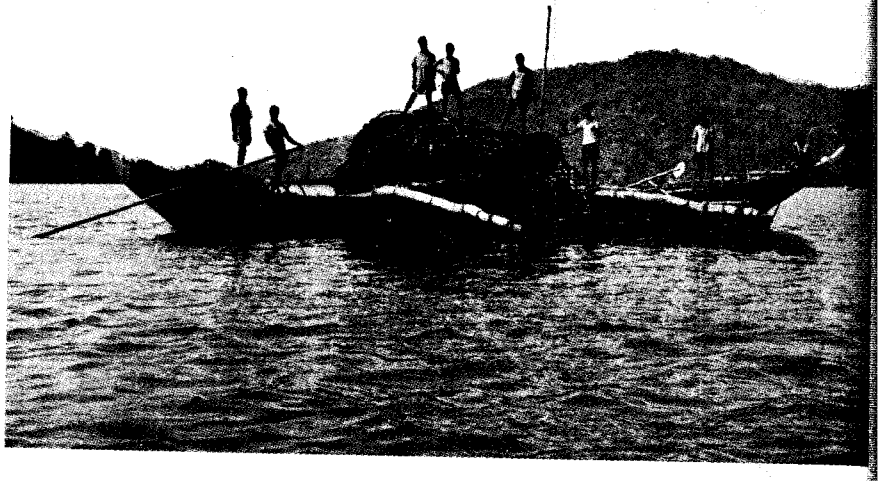


Fig. 9 — *Rampan* boat with *Rampani* net

narrow keel and spreading upper planks. Its dimensions are: length 15.2 m., breadth 1.8 m. and depth 2.7 m. and is used with outrigger arrangement for the operation of the shore-seine, *Rampani* (Figs. 9 and 10).

The tackle used in the oil sardine fishery has attained the maximum limited efficiency during the course of several years and consists of nets which are ideally suited for the capture of this pelagic shoaling fish in the inshore waters. The common nets used in the fishery up to the end of the last century were the boat-seines, drift-nets and cast-nets. With the installation of fish oil and guano factories in 1908 more efficient types of nets were introduced to meet the growing demand from these factories. The high prices offered by them for even stale fish induced the fishermen to go regularly for night fishing with these new nets. These nets are the boat-seines (*Mathikolli vala*)

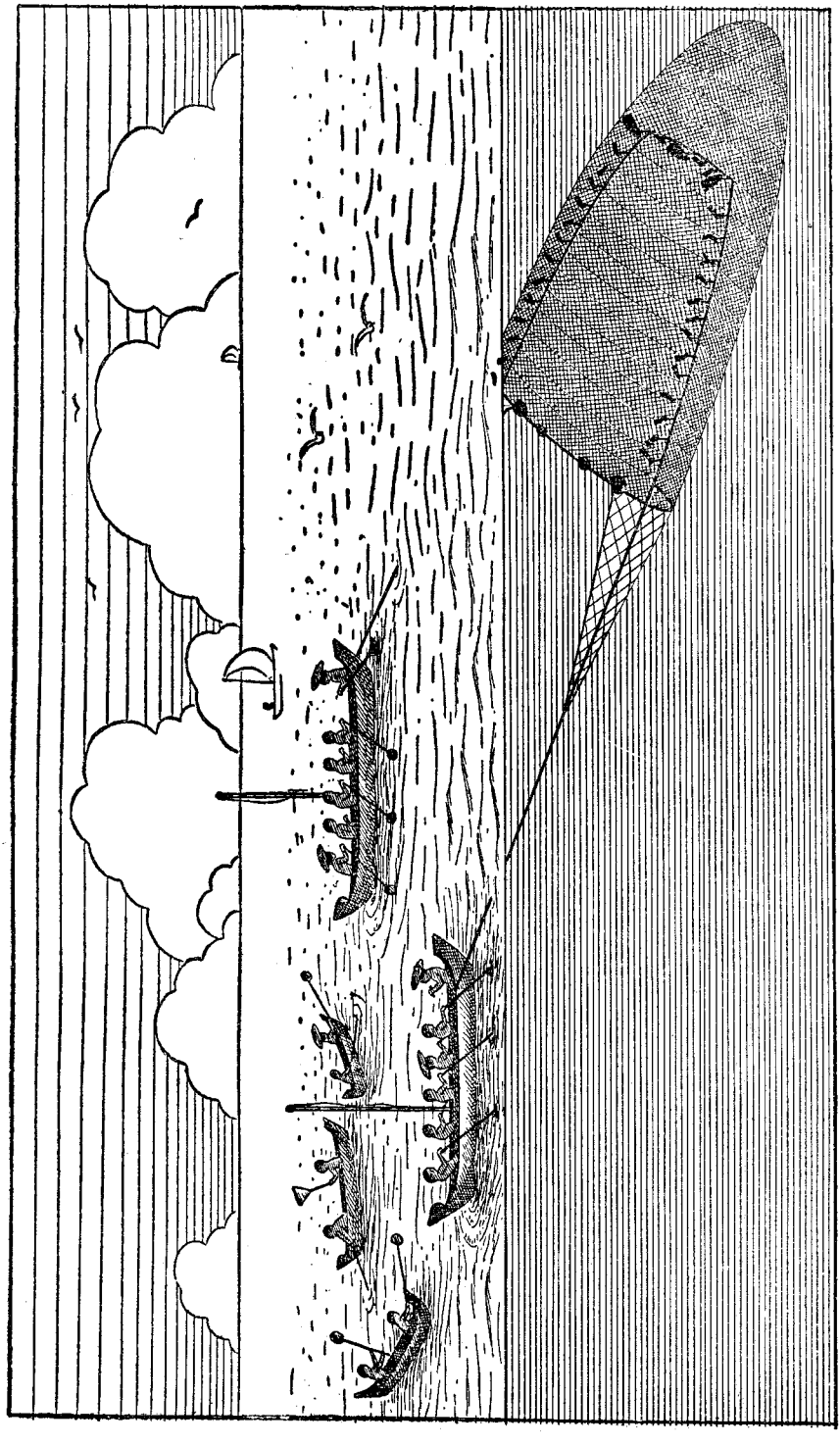
Fig. 10 — Hauling of *Rampani* net

ınd the gill-net (*Mathichala vala*) used along the Malabar coast and the shore-ɜeine (*Rampani*) used along the Kanara coast. The former two nets consti-ːute an efficient tackle for the capture of the shoals in the open sea while the *Rampani* is used only when the shoals enter the very shallow inshore waters.

Mathikolli vala is a boat-seine made of cotton and is used exclusively for ːhe capture of oil sardines during the peak period of the fishery. The dimen-ɪions of the net are: length 18.2 m., breadth 5.5 m. and mesh size 16 mm. ɪt consists of a wide mouthed bag, a platform and two wings and is operated ɔy two dug-out canoes. Half of the net is carried in each canoe and when the ɪhoal is sighted the canoes separate paying out the net. The encircled shoal s driven into the net by the loud noise produced by fishermen in auxiliary ɔoats (Fig. 11).

Mathichala vala is a gill-net made of cotton and is used for catching sardines ɔnly. The dimensions of the net are: length 10.9-27.4 m., breadth 3.6-5.4 m. ınd mesh size 9-16 mm. The net is operated from two canoes. Each canoe ːarries 4 to 8 such pieces of nets laced together and when the shoal is sighted ːhe net is paid out quickly from both the canoes in a semi-circular manner ıcross the direction of movement of the shoal which gets encircled by the net. Ihe terrific noise and splashing produced by the fishermen make the oil sardi-ıes panicky and in their attempts to escape from the net get themselves firmly gilled in the opercular region (Fig. 12).

Rampani is a very large shore-seine used for catching shoals of oil sardine ınd mackerel when they enter the shallow inshore waters. The net is made ɔf hemp and consists of about 100 pieces linked together. The dimensions ɔf each piece are: length 10.9 m., breadth 6.0 m. and mesh size 19-25 mm. One end of the net is held by a party of about 40 men in the shore and the net ɪs carried in the *Rampani* boat and is paid out in a semicircular way encircling ːhe shoal. The other end of the net is brought ashore and is handed over to ınother party of men. The two ends of the net containing the shoal are slowly dragged by the two parties. Large quantities of these fishes sometimes weighing several tonnes are landed in one haul of the net.



Several types of specialized nets like the boat-seine (*Paithu vala, Pattenkolli vala, Thattum vala, Thangu vala* and *Nethel vala*) and shore-seines (*Kamba vala, Kairampani* and *Yendi*) with varying mesh size designed for the capture of other shoaling fishes are also used in the oil sardine fishery.

Fishing Season

The oil sardine fishery usually commences in July and terminates in March with the November-January portion representing the peak period of the fishery.

UTILIZATION

As Food

The oil sardine is esteemed as a very valuable food fish and since it is subject to easy spoilage only limited quantities are consumed in the fresh condition. Fresh sardines are packed with crushed ice in dealwood boxes and sent by train from some of the important sardine centres of the west coast to larger towns like Madras, Coimbatore, Bangalore and Trichy. In addition to this, carrier launches also transport oil sardine to Bombay from the Rampan operating centres. The major portion of the catch is, however, cured with salt in the proportion ranging from 6:1 to 9:1 and sun-dried. The Ratnagiri method of wet curing is practised in Kanara by using salt in the proportion of 3:1.

Sardines were canned successfully by a French canner, M. de Josselin, at Mahe for many years before the establishment in 1911 of a State cannery at Kozhikode to demonstrate the possibility of producing a quality canned product in India comparable to the imported varieties. The shifting of this cannery in 1911 to Chaliyam at the mouth of the Beypore river facilitated supplies of fresh sardines and mackerel from the sea soon after capture. The preservation of fish in sardine oil, curry, tomato and mustard sauces was successfully tried for packing purposes and the products were in great demand both in and outside India. The samples exhibited at the Wembley Exhibition, London, in 1924 received commendations but unfortunately many technical and practical difficulties encountered during the post-war years resulted in the closing of the factory in 1933. The last one decade witnessed the revival of the canning industry and at present there are several private factories engaged in canning sardines.

The following chemical composition of the oil sardine has been recorded by Chari (1948): Edible portion, 70.00; Protein, 19.57; H_2O, 76.49; Ash, 1.79; P_2O_5, 0.79; CaO, 0.47; and Fat*, 2.03%; and Iron, 6.09 mg./100g.

*The fat content is known to vary up to 15 per cent depending on the size, sex and season.

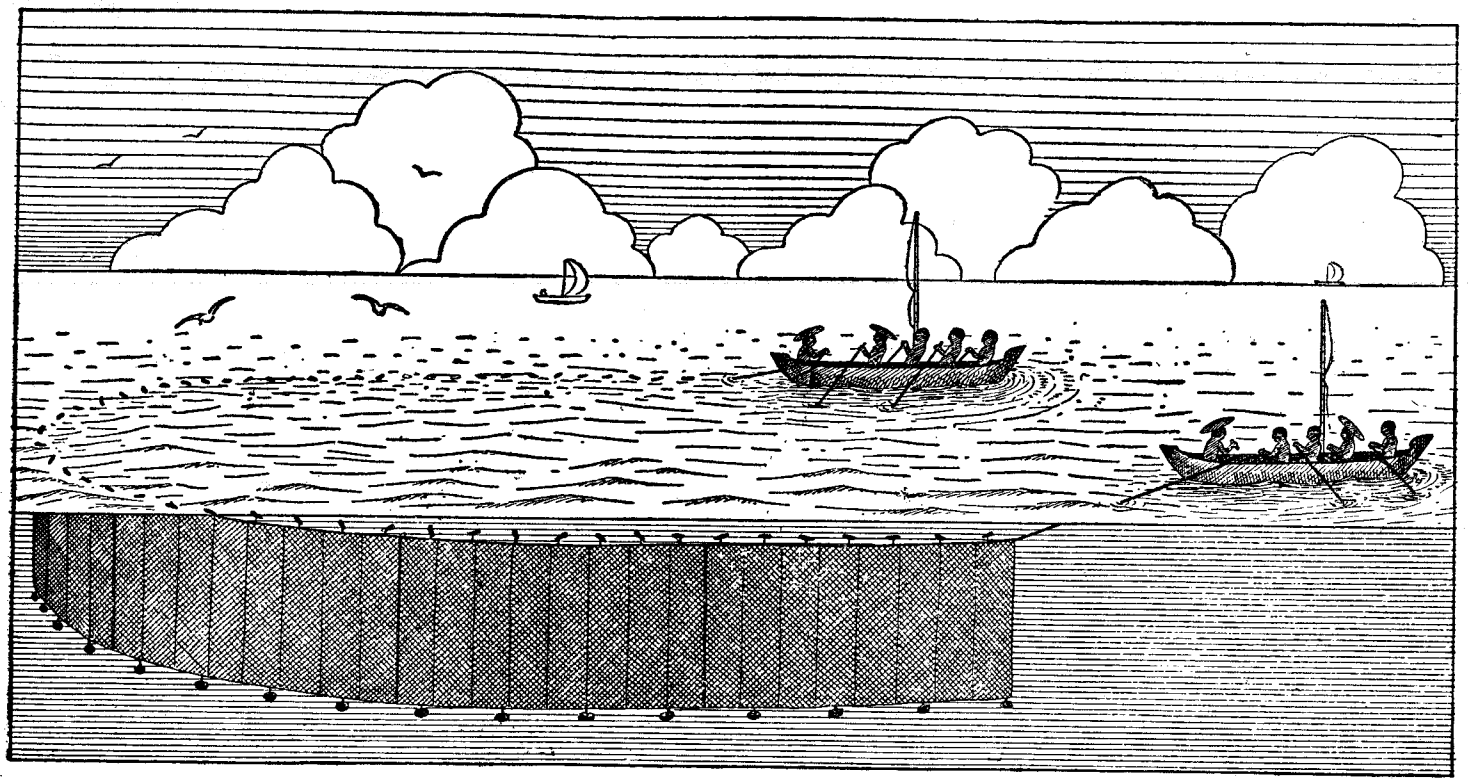


Fig. 12 — Diagrammatic sketch of sardine fishing by *Mathichala vala* (gill-net) (Sketch by author, from Panikkar, 1952)

Sardine Oil and Guano

The existence of the oil sardine fishery is known from time immemorial and as early as 1320, Odoric* noted when he visited Ceylon, that "there are fishes in those seas that come swimming towards the said country in such abundance, that for a great distance into the sea nothing can be seen but the backs of fishes which, casting themselves on the shore do suffer men for the space of three daies to come and take as many as they please." Nieuhoff (1673)* also noted that the sardines were abundant in these waters. Dussumier (1827)* observed that the sardines were utilized as manure for paddy and coconut plantations since they were found unfit for curing owing to the high oil content of the fish. Day (1865) also emphasized that owing to the ignorance of the abundance and uses of the oil sardines, they were mostly captured to manure the land and for feeding the livestock; the quantity actually consumed being very little when compared with the abundance of the catches. He also observed that "it is only of late years, since animal oil has become so dear, partially due to a deficiency of that of the whale, that attention has been directed to the immense shoals of sardines, which are found off Malabar and Ceylon." The demand for fish oil from Europe and elsewhere gave an impetus to the sardine oil industry and the new trade which was non-existent before developed rapidly during the early years. A decline was noted during certain years partly caused by the diminution in the abundance of the shoals of oil sardines. However, the average annual export value of sardine oil from Malabar was well over £ 7,000. Day emphasized the adverse effects of this growing sardine oil industry on the valuable fishery. Thurston (1900) also attributed the decline in the sardine oil trade to the erratic and undependable nature of the oil sardine fishery.

Another phase in the exploitation of the oil sardine fishery commenced with the beginning of this century when Nicholson (1915) helped the revival of the sardine oil industry by the introduction of an improved method in 1908 for the extraction of the oil. The practice till then in vogue was very crude and primitive and the products of a very inferior quality. The sardines were allowed to putrefy in an old and worn-out canoe in the open sun. Sometimes the boat was divided into two compartments by a perforated iron sheet and the sardines were allowed to decompose in one compartment and the exuding oil which collected in the other compartment was skimmed off. The oil produced by this method was of the worst quality and description and the residue was generally thrown into the sea. A low grade fertilizer was also prepared by allowing the fish to rot and dry on the beach. Large quantities of valuable oil, injurious to the crop, was wasted by this method and the product was also found deficient in the valuable nitrogen and phosphate contents. With a view to stop this wasteful procedure, Nicholson (1915) after some preliminary experiments recommended the adoption of an improved method by which the sardines were thoroughly boiled in cauldrons over open fire and the resulting

oil ladled out into buckets containing cold water and finally washed and dehy drated. The boiled fish was put in coir bags and pressed in the indigenou screw-presses to separate the second grade oil. The residue in the bag wa broken up and sun-dried to form the guano. Nicholson's move to revive th sardine oil industry met with immediate success. The new method was firs adopted by a merchant in Cannanore who produced better quality oil an guano of good manurial value and his success led small capitalists to insta several such factories throughout the coasts of Malabar and South Kanara The number of oil and guano factories increased rapidly and the maximun figure of 647 factories was reached during the season 1922-23 or approximatel 2 factories per kilometre of the coastline. The production of oil and guan also showed record figures of 12,000 and 33,500 tonnes respectively during th season. In the subsequent years, however, the fall in the trade of oil an guano was caused mainly by the malpractices of the traders who were induce to do them by the high prices prevailing then, and partly by the extreme annua fluctuations seen in the oil sardine fishery. The complete failure of the fisher during the forties rendered all the oil and guano factories idle and the produc tion of these bye-products of the fishery came to an end.

The crude oil extracted during the earlier years of plenitude was used locall as a preservative for boats against weathering and shipworm attacks. Tw grades of refined oil were later obtained by the improved method of whic the first grade yellow oil was used in the leather industry and in arsenals an the second grade brown oil in the jute and steel industries, as lubricants an as the base for good quality insecticidal soaps. Good quality sardine oil ca be preserved for one year without much deterioration (Kamasastri, 1960) The refined Indian sardine oil was found to compare very well with the Men haden or the Japanese sardine oil as may be seen from Table 11 (Nicholson 1922).

Sardine oil has a high vitamin A content, but it is observed to deteriorat rapidly under storage. For well over a century sardine oil was exported t U.K., Germany, Turkey and other countries.

The high nitrogen and phosphate contents of fish guano have made it valuable manure for cash crops and plantations. The difference in th

Table 11 — Qualities of Menhaden, Japanese and Indian Sardine Oils

Oil	Specific gravity	Saponification value	Iodine value	Acid value
Menhaden oil	0.93	193	160	7
Japanese sardine oil	0.93	195	181-187	10-34
Indian sardine oil	0.88	196	156	3-9 12-53

Table 12 — Composition of Crude Manure and Improved Guano

	Beach dried manure %	Improved guano %
Water	15.0	9.77
Nitrogen	6.8	8.31
Phosphoric acid	5.3	8.82
Potash	0.7	0.40
Total organic matter	60.0	66.28

composition between the crude beach dried manure and the improved guano may be seen from Table 12 (Nicholson, 1922).

The improved guano has been in great demand in coffee, tea, coconut, sugarcane and tobacco plantations and exported mostly to Colombo and Japan.

Sardine Meal

Sardine fish-meal specially prepared in factories after the complete removal of the oil was in great demand with the livestock owners. Its composition is as follows (Chari & Pai, 1948): Moisture, 9.68; Protein, 65.27; Fat, 9.54; Ash, 14.77; P_2O_5, 5.79; CaO, 6.01; NaCl, 0.32; Insolubles, 1.78; and Unidentified, 0.75%.

t

BIOLOGY OF THE LESSER SARDINES

Sardinella gibbosa (Bleeker) (Fig. 13) syn. *Clupea gibbosa* Bleeker, 1849; *C. fimbriata* (Part) Day, 1878, 1889; *C.* (*Harengula*) *fimbriata* (Part) Weber & Beaufort, 1913; *Sardinella gibbosa* Regan, 1917, Herre, 1953; *S. jussieu* Fowler, 1941.

Malayalam: *Chalamathi*; Tamil: *Choodai*, *Nonalai*; Telugu: *Kavallu*; Kannada: *Erebai.*

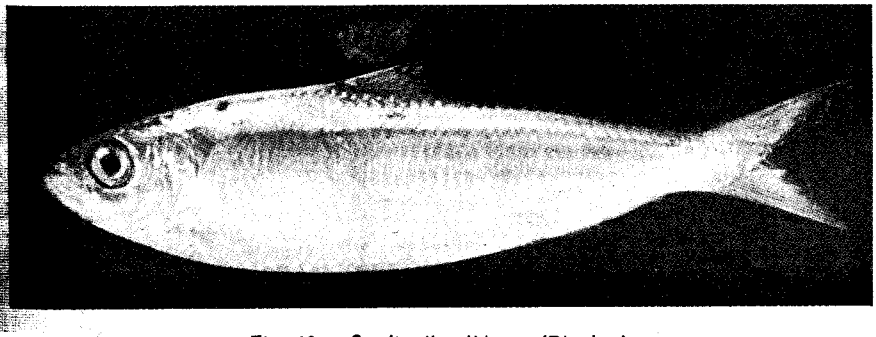


Fig. 13 — *Sardinella gibbosa* (Bleeker)

Description

Depth of body 3.5 to 4 in length, length of head 4-4.3. Snout as long as or longer than diameter of eye, which is 3.5-4 in length of head; maxillary extending to below anterior 0.25 or 0.33 of eye; 50-55 gill-rakers on lower part of anterior arch; 44-48 scales in a longitudinal, 11-13 in a transverse series; ventral scutes 18-20+13-15. Dorsal 17-20. Anal 17-19. Pelvic 8-rayed, somewhat in advance of middle of dorsal. A dark spot at base of anterior dorsal rays; upper part of dorsal and posterior edge of caudal often dusky (Regan, 1917).

Distribution

East Africa, Madagascar, Arabia, India, Malay Archipelago, Australia, Polynesia, Micronesia, Philippines, China.

Differential Distribution

Along the Waltair coast Ganapati and Rao (1957) observed that this species migrates to the offshore spawning grounds in February beyond the normal range of fishermen's operations, when it is about 11 cm. in length and after spawning the post-larval and juvenile fishes of 3-9 cm. start returning to the coastal waters in April.

Sekharan (1955) also noted differences in the distribution of the size groups of the sardines caught in the gill-nets and shore-seines in the Palk Bay. He observed that during March-July when the larger size groups representing one-year-old sardines are found in the gill-net catches operated 8-10 km. offshore, they are completely absent in the shore-seine landings operated within one to one and half miles from the shore. Some differences in the size groups that constitute the catches of these two nets were also noticed during the other months and he suggested that the sardines when they grow beyond a particular size tend to prefer deeper waters further offshore.

Seasonal Variation

The *choodai* fishery of Palk Bay is mainly constituted by the juveniles of *S. albella* (Cuv. & Val.) and *S. gibbosa* (Bleeker) which occur in the coastal waters from March and April to October-November. After this period the Palk Bay becomes rough and the fishing activities are shifted to the Gulf of Manaar up to March where the fishery is relatively poor (Sekharan, 1955). Sekharan's detailed study of the size groups of *choodai* caught with the different nets in different localities further shows that only very young sardines below a modal length of 5.0 to 5.4 cm. are caught with torch and hand nets while shore-seine catches are mainly composed of the 0-year class throughout the season. The gill-nets also land the 0-year class, but from March to August this gear captures the one-year-old sardines. The catches of the boat-seine also consist mainly of the 0-year class and to some extent of older fish. The modal sizes of the sardines of the boat-seine catches are intermediate between those of the shore-seines and gill-nets especially from April

to August. Regarding the operation of the shore-seines, Sekharan (1959) mentioned that the nets are provided with different mesh sizes at the cod end which are changed according to the size of the sardines in the available population. In the beginning of the season when the population consists of very young fish, shore-seines are fitted with bags of smallest mesh size. The bags with intermediate mesh size are used in May and June when there is a dearth of young fish and the third type is used from July onwards. He further stated that about 95 per cent of the *choodai* fishery was composed of juveniles belonging to the 0-year class most of which are landed by the shore-seines operated in the very shallow inshore waters.

According to Prasad (1953) the young sardines congregate in the inshore waters to feed on the abundant diatoms and copepods found at that time of the year. He also pointed out that swarms of *Noctiluca* which appear about that time have a deleterious effect on the *choodai* fishery and suggested that this dinoflagellate could be considered as an indicator species of poor *choodai* fishery. Devanesan (1942) also pointed out that the abundance of the inedible *Noctiluca* may have a bearing on the scarcity of the oil sardine on the west coast.

Bionomics

Age and Size at Maturity

According to Chacko (1946), this sardine attains sexual maturity in the Palk Bay and the Gulf of Manaar regions when it reaches a length of 14 cm. Sekharan's (1955) investigations on the sardines occurring in the same regions showed that fish below 8.5 cm. were immature and a proportionate increase of mature fish is observed in the higher size groups with most of the sardines of the 10.7 cm. size groups being mature. He concluded that maturity is attained at this size at the end of the first year.

Ganapati and Rao (1957) computed the ponderal index of both males and females belonging to the different size groups of sardines found in Lawson's Bay and noticed that it decreased with increase in length up to 11 cm. and thereafter it showed a marked rise in both the sexes; but in the females an inflexion of the curve in the K values was noticed at 12 cm. These authors, therefore, believed that the females attain maturity at the average length of 11-12 cm. They confirmed this observation by a study of the gonadial maturity of the sardines.

Spawning Season

Chacko (1946) collected sardines with fully transparent eggs in December and January and partly or fully spent sardines in January and February from Palk Bay and the Gulf of Manaar. He inferred that this sardine has a single prolonged spawning season extending from September to February. In the Palk Bay and the Gulf of Manaar, Sekharan (1955, 1967) found a very high percentage of males and females in the penultimate stage of maturity during

March and April. He also found the appearance of small sardines in April and based on these observations he suggested that the spawning season of *S. gibbosa* (Bleeker) extends from February or March to June or July. He also believed that the majority of the individuals spawn only once during a restricted period as shown by the presence of only one batch of maturing eggs clearly differentiated from the general egg-stock in the ovaries.

In the Tuticorin Bay, Chacko (1956) observed that the shoals seen during June, July and August are mainly composed of sardines belonging to 10-14 cm. size groups with the gonads in different maturity stages with the majority of the females in advanced stages of maturity. In September the shoals are composed of spent individuals. He believed that the spawning season of the sardine is limited in this region to August and September.

Ganapati and Rao (1957) utilized the mean condition factor of both males and females in the successive months for determining the spawning season of the sardine found in Lawson's Bay. They found that the K value was at its height in September with a steep fall in October which is believed to be caused by the growth of the fish in linear dimensions. Thereafter a steady increase was noted till it reached another maximum in March in the case of the females and April in the case of males, and the values were considerably high up to June. Based on these observations they indicated that the spawning period of the fish commences in March or April and extends up to May or June. They also found mature specimens in the commercial catches in May and eggs presumed to belong to *S. gibbosa* (Bleeker) from February to June in the plankton collections.

Dharmamba (1959) studied the spawning habits of the sardine occurring in the same locality and confirmed the conclusions of Ganapati and Rao (1957) regarding the spawning season. Maturing sardines were collected by her from February to May and they continued to appear in June and July also in very small numbers. She noted the maximum occurrence of the maturing sardines during February and March. Fully mature sardines were not collected by her and she also believed that they probably migrate for spawning away from the coast beyond the present fishing grounds. Based on the occurrence of maturing fishes she suggested that the spawning season commences in February and extends up to June with a peak period from February to April. She pointed out that the occurrence of post-larvae and juveniles of the sardine during March to May gave additional evidence that spawning takes place during this period.

Dutt (1961) found along the Waltair coast maturing and mature adults ranging in length from 13 to 18 cm. from February to April and stated that there is definite evidence of spawning in the area. He pointed out that the occurrence of the same length groups during two different months of the season with an interval of at least three months, suggests the possibility of two spawning periods or two spawning stocks.

The ova diameter frequency studies carried out by Dharmamba (1959) confirmed the observations of Sekharan (1955) regarding the periodicity of

spawning and she stated that the sardine has a definite short spawning period with a single spawning each season. She found in the nearly mature and mature ovaries a single batch of large maturing or mature ova sharply separated from the general egg-stock. She also pointed out that even though the spawning season of the individual fish is restricted to a short period, the spawning season of the species extends for about five months from February to June which indicates that all the individuals of the species do not mature and spawn at the same time.

Early Life-history

Egg—Chacko (1946) collected the planktonic eggs of the sardine measuring 0.58-0.64 mm. from the Palk Bay and the Gulf of Manaar. He also found that the ripe ovarian eggs measured 0.56-0.60 mm. in diameter. Chacko (1950) later stated that the diameter of the eggs of this sardine varies from 0.68 to 0.84 mm. and that they are provided with an yellow frothy yolk in which one small oil globule is present.

Larva—Chacko (1946) noted the presence of 29 preanal myotomes only in the larva. It was pointed out by Nair (1959) that the planktonic eggs attributed by Chacko to *S. gibbosa* (Bleeker) are not sardine eggs since they do not possess the wide perivitelline space which is an important character of sardine eggs. The anterior position of the anus below the 29th myotome in the larva described by Chacko is also not a feature of the sardine larvae which generally show 37-40 preanal myotomes (Delsman, 1926 a).

Adult

Growth—Sekharan (1955) studied the growth of *S. gibbosa* (Bleeker) found in the Palk Bay and the Gulf of Manaar during 1952 and 1953. He found that the 1952 year class recruits attained the size of 10.7 cm. while the 1953 year class recruits reached a size of 12.2 cm. during the first year. He suggested that the rate of growth in the sardine appears to vary from year to year which is probably due to the changes in the environmental conditions and density of population. Determination of the subsequent growth rate of the sardine has not been made by him since the fishery is constituted mainly by the juveniles composed of the 0-year class.

Food and Feeding Habits—The food and feeding habits of the sardine occurring in the Gulf of Manaar was made by Devanesan (1932) and according to him there is very little difference in the nature of the food taken by the different size categories. He found that the bulk of the diet consisted of crustaceans composed of zoea larvae, copepods and *Lucifer*. Among the phytoplanktonic organisms, *Trichodesmium erythraeum* Ehrenberg formed the chief food. He also noticed that whenever the blue-green alga is abundant in the plankton the stomach of the sardine is found to be gorged with it. Larval bivalves ranked third in importance in the diet of the sardine. Devanesan stated that the inclusion of large organisms like *Lucifer* must have been the result of definite acts of capture involving quick efforts on the part of the

fish. The presence of minute zoea stages, copepods and *Trichodesmium* was attributed by him to a process of straining by the gill-rakers and suggested that the fish probably seeks the regions where such organisms are found in abundance. According to him, the fish exercises a certain amount of selection of food and does not swallow indiscriminately, the planktonic organisms which come in its way. He found some of the stomachs empty and believed that the sardines probably have intervals when they do not show feeding activity. He also found the occurrence of foraminiferans in the stomach contents of the sardines caught in the shallow waters and these were invariably found with sand particles. He therefore, suspected that the sardines also feed on the littoral deposits of foraminifera.

Devanesan (1942) again pointed out that the blue-green alga, *T. erythraeum* Ehrenberg found in the plankton off Krusadai in large quantities during certain seasons forms a favourite food of *S. gibbosa* (Bleeker) and suggested that the fishery depends to a certain extent on the abundance of the alga. On the other hand, John and Menon (1942) pointed out that the occurrence of large patches of *Trichodesmium* on the Trivandrum coast at intervals between December and April is found to have an inhibiting influence not only on plankton feeding fishes but also on certain planktonic organisms themselves. They, however, found some specimens of *S. melanura* (Cuv.) showing plenty of this alga in their gut contents on one occasion and suggested that it might be an exceptional case of indiscriminate feeding. Chidambaram (1942) thought that the inhibitory influence of *Trichodesmium* is more due to its occasional profusion than to its unpalatable qualities and suggested that on account of the sheer thickness of the floating algal layer the fish may react negatively to it. He also found this alga as an occasional item of food of the mackerel, oil sardine and *S. gibbosa* (Bleeker). Nair (1953 b) also observed the presence of *Trichodesmium* in large numbers in the stomach contents of the oil sardine during December 1949 and April 1950. This blue green alga is also known to cause mortality and Chacko (1942) and Chidambaram and Unny (1944) have recorded interesting cases of mortality among marine animals including fishes in the Gulf of Manaar. In these cases mortality is believed to be caused by asphyxiation and also by putrefaction and pollution of the sea-water by the dead alga.

Chacko (1946, 1949) studied the food and feeding habits of *S. gibbosa* (Bleeker) found in the Palk Bay and the Gulf of Manaar and he stated that this sardine is a plankton feeder and that crustacean larvae, pteropods and *Trichodesmium* form the chief food. He noticed the presence of foraminiferans in the stomach contents on certain days and thought the sardines feed on their ooze. Fish larvae were found in some specimens examined by him.

Devanesan and Chidambaram (1948) stated that both *S. gibbosa* (Bleeker) and *S. albella* (Cuv. & Val.) feed on planktonic organisms like *Lucifer*, *Sagitta*, crab larvae and *Trichodesmium*.

The food of this sardine occurring in the Tuticorin Bay was studied by Chacko (1956) and he found that the food of the juvenile, mature and spent

individuals consists mainly of diatoms, copepods, dinoflagellates and larvae bivalves. Sand particles were observed by him in the stomachs of many specimens and he suggested the possibility that the juveniles show a bottom feeding habit in the inshore regions.

Ganapati and Rao (1957) made a detailed study of the food of this sardine occurring off the Waltair coast. They noticed that young prawns, larva of *Acetes* and *Alpheus* are the common food elements forming a very large proportion of the food throughout the year. *Undinula*, *Centropages*, *Eucalanus*, *Macrosetella* and *Oncaea* are the important copepods found to contribute to the food of this sardine. The other food elements noted by them are *Lucifer*, decapod and gastropod larvae and post-larvae of *Anchoviella*. These authors also made a comparative study of the constituents of the food and the plankton for determining their relationship and they found that there is no correlation between them in respect of the relative abundance of the different types of organisms. However, they found that smaller organisms like copepods, larval crustaceans and diatoms conformed to some extent with their abundance in the plankton whereas the larger organisms like the fish larvae and young prawns are seen more frequently in the stomachs than in the plankton. They, therefore, believed that *S. gibbosa* (Bleeker) is an omnivorous selective feeder preferring only certain food items present in the plankton and does not swallow indiscriminately the planktonic organisms present in the environment. The presence of larger crustaceans and young fishes which are themselves active swimmers led them to believe that the sardine exercises a definite selective action in the capture of food. They also indicated the possibility that the fish seek regions where the smaller planktonic organisms occur in abundance and obtain their food also by straining.

Ganapati and Rao (1957) pointed out that active feeding by the juveniles and spent sardines takes place during March and April. The intensity of feeding is lowest from May to September coinciding with the fall in the abundance of zooplankton in the coastal waters. They observed a gradual rise in the intensity of feeding in the subsequent months.

Population

Sex Ratio—In the Tuticorin Bay, Chacko (1956) observed that the shoals seen during June to August are composed of sardines measuring 10 to 14 cm. in length with their gonads in various stages of development. He found that the majority of the fishes occurring at this time are females in advanced stages of maturity. Ganapati and Rao (1957) on the other hand, observed that the percentages of mature males are greater than mature females in Lawson's Bay and they attributed this difference in sex ratio to the migration of the ripening females beyond the normal range of fishermen's operations.

Age Composition—Based on the accounts given by Sekharan (1955, 1959) some information is available about the age composition of the commercial catches in the Palk Bay and the Gulf of Manaar. In these regions the fishery is mainly supported by the juveniles belonging to the 0-year class.

The one-year-old sardines also enter the fishery, but the contribution mad by them is negligible. No other age group is found to occur in the loca fishery. The shore-seines which are the main gear used in the *choodai* fisher catch mainly the 0-year class while the gill-nets land only the one-year class Boat-seines generally show a mixed catch of 0- and one-year classes, th former being more abundant.

Size Composition—Chacko (1946, 1949) stated that the commercial catche in the Palk Bay and the Gulf of Manaar consist mainly of fish measurin 13-15 cm. in length, but in April and May large numbers of young sardine 5 to 10 cm. in length occur in the shallow waters.

Sekharan (1955) made a detailed study of the length frequency of th sardines occurring in the commercial catches in the Palk Bay and the Gul of Manaar and the changes in the modal size composition noted by him ar given in Table 13.

Sekharan (1959) in a subsequent paper has indicated in a general way the size composition of the sardine together with their modal size caught by the different fishing units, namely hand-net and torch, shore-seines, boat-seines and gill-nets. Table 14 gives the modal size of *S. gibbosa* (Bleeker) when the year classes 1952 to 1955 were first caught in the various nets.

Table 13 — Modal Size Composition in Commercial Catches

Year	Months	Modes
1952	April	3.7, 10.7-11.2
	May	5.7, 10.7
	June	5.7-6.2, 10.7
	July	6.7
	August	7.2
	September	8.7
	October	9.2
	November	9.7
1953	March	10.7
	April	10.7
	May	4.2, 10.7
	June	6.2
	July	7.2
	August	8.2
	September	8.7, 12.7
	October	9.2
	November	10.2
	December	10.7
1954	January	11.2
	February	12.2
	March	12.2

Table 14 — Modal Size (cm.) of *S. gibbosa* Caught in Different Nets

	Year classes			
	1952	1953	1954	1955
Hand-net	3.0-3.4	...	2.5-2.9	3.5-3.9
Shore-seine	3.5-3.9	...	2.5-2.9	...
	6.0-6.4	4.0-4.4	4.5-4.9	4.5-4.9
	6.5-6.9	6.0-6.4	6.5-6.9	6.0-6.4
Boat-seine	...	6.5-6.9	6.0-6.4	7.0-7.4
Gill-net	...	10.0-10.4	8.5-8.9	9.0-9.4

Table 15 — Measurements (cm.) of *S. gibbosa* from the Vellar Estuary

Year	Month	Cast-net/shore	Cast-net/craft
1952	May	...	7.6-10.2
	June	...	7.6-10.2
	July	7.6-11.4	5.1-7.6
	August	7.6-10.2	5.1-8.8
	September	...	...
	October	...	5.1-10.2
	November	...	7.6-15.2
	December	7.6-11.4	12.7-17.7
1953	January	...	10.2-17.7
	February	...	10.2-19.1

Discussing the various factors influencing the size composition of the catches he pointed out that the foremost among them are the fishing methods themselves as shown by torch fishing the success of which entirely depends upon the attraction of young sardines to a source of light and where the catch reflects the size composition of the shoals.

Chacko *et al.* (1954) made a study of the Vellar estuary at Porto Novo for a period of one year from May 1952 to April 1953. They made a monthly study of the size range of *S. gibbosa* (Bleeker) which contributes to a good fishery in the estuary during October to January. The measurements of sardines caught with cast-nets operated from the shore and from a craft in deeper waters are given in Table 15. They pointed out that the latter yielded better catches of sardines.

The shoals of the sardine occurring in the Tuticorin Bay during June to August are composed of fish measuring 10-14 cm. in length (Chacko, 1956). He observed a fresh recruitment of juveniles measuring 10-11.5 cm. during November and December.

Predators—*Chirocentrus dorab* (Forskal), *Otolithus ruber* (Schn.), *Lactarius lactarius* (Bl. & Schn.) and *Sphyraena obtusata* Cuv. are the predators of this sardine (Chacko, 1946).

Parasites—Entozoic trematode parasites belonging to the genera *Aponuru* and *Hemiurus* are recorded from the stomach of the sardine occurring a Waltair. The infection by the former is very intense during the month o February. Nematode parasites are occasionally found and among th ectozoic parasites *Caligus* is reported from the buccal cavity of the sardin (Ganapati & Rao, 1957).

Tagging Experiments—Hamre *et al.* (1966) tagged and released 30 *S. gibbosa* (Bleeker) in December 1966 at Panjim, Goa, with the aim of evolvin a suitable method of tagging fish. The tagged *S. gibbosa* ranged between 1 cm. and 16 cm. in total length. No signs of adverse effect have bee observed in the tagged fish until they were released in the sea six hours afte tagging. There is no information on the recoveries, if any, of the tagge sardines.

Sardinella albella (Cuv. & Val.) (Fig. 14) syn. *Kowala albella* Cuv. & Val. 1847; *Clupea albella* Günther, 1868; *C. brachysoma* Day, 1878, 1889; *C. (Harengula) brachysoma* Weber & Beaufort, 1913; Regan, 1917; *Sardinella brachysoma* Herre, 1953; *S. albella* Fowler, 1941.

Common Indian names are same as those of *Sardinella gibbosa* (Bleeker).

Description

Depth of body 2.5 to 3 in length, length of head 4 to 4.5. Snout shorter than diameter of eye, which is 3 to 3.3 in length of head; maxillary extending to below anterior 0.3 of eye or a little beyond. 55-65 gill-rakers on lower part of anterior arch. 40-44 scales in a longitudinal and 12 or 13 in a transverse series; ventral scutes 17-20 + 12-13. Dorsal 17-20. Anal 18-22. Pelvic 8-rayed, below or in advance of middle of dorsal. A dark spot at base of dorsal; upper part of dorsal and ends of caudal lobes often dusky (Regan, 1917).

Distribution

Zanzibar, India, Malay Archipelago, Australia, Philippines and China.

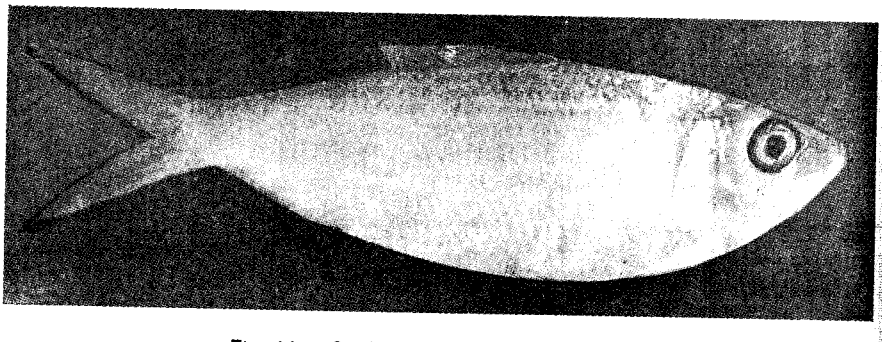


Fig. 14 — *Sardinella albella* (Cuv. & Val.)

Differential Distribution

The *choodai* fishery of the Palk Bay and the Gulf of Manaar is composed of *S. albella* (Cuv. & Val.) and *S. gibbosa* (Bleeker) of which the former is the most abundant species. The differential distribution given by Sekharan (1959) in the case of *S. gibbosa* (Bleeker) is applicable for this species also. These two sardines appear to have a sort of mutually repellent relationship and when one is abundant in the catches the other is scarce (Sekharan, 1967).

Seasonal Variation

Same as that of *S. gibbosa* (Bleeker) in the Palk Bay and the Gulf of Manaar (Sekharan, 1955, 1959).

Bionomics

Age and Size at Maturity

The maturity studies conducted by Sekharan (1955) in the Palk Bay and the Gulf of Manaar showed that sardines less than 9 cm. in length are immature. Mature specimens are first seen in the 9-9.5 cm. size groups and he found 87 per cent of the sardines mature at a length of 10.7 cm. All the sardines above this size were fully mature. He suggested that *S. albella* (Cuv. & Val.) becomes mature when it reaches 10.7 cm. in length at the end of one year. Chacko and Mathew (1956 a) stated that mature individuals measuring 15-17 cm. appear along the west coast in March and spent ones in April. These authors believe that maturity is attained by the fish when it measures 15 cm. in length.

Fecundity

Radhakrishnan (1961) studied the fecundity, maturation and spawning of *S. albella* (Cuv. & Val.) based on sardines obtained from Karwar. He noticed that the approximate number of mature eggs in the ovaries of the gravid females measuring from 14.6 to 15.5 cm. varied from 10,000 to 13,500. The left lobe of the ovary, which is larger than the right lobe, produces more eggs, the number being directly proportional to the size of the ovary. The maximum diameter of the intra-ovarian egg recorded was 1.02 mm. The ripe eggs varied from 0.68 to 1.02 mm. in diameter. In mature ovaries there is a distinct batch of ripe eggs clearly separated from the immature stock and the ripe stock of eggs have a wide range in diameter. These features indicate that the species spawns once a year, but the duration of spawning may extend over a long period.

Spawning Season

The spawning season of this sardine is the same as that of *S. gibbosa* (Bleeker) in the Palk Bay and the Gulf of Manaar (Sekharan, 1955). The ova diameter studies carried out by him showed that there is only one distinct

batch of maturing eggs clearly separated from the immature general egg-stock indicating that the fish spawns only once every year during a short restricted spawning season. According to John (1939) this sardine spawns on the west coast from April to June. Chacko and Mathew (1956 a) suggested that the breeding season is during the pre-monsoon months extending from March to May along the west coast.

Early Life-History

Egg—Delsman (1926 a) collected the eggs of this species from the Bay of Batavia and stated that the presence of a double egg membrane and a small oil-globule is a distinguishing feature of the egg of this sardine. The diameter of the egg, including the outer egg membrane varies from 1.1 to 1.2 mm. The outer membrane is very thin and gets wrinkled easily. The inner one is less spacious and often not perfectly spherical with a longer diameter of about 0.98 mm. and a shorter diameter of about 0.94 mm. The inner membrane is thick and its contents somewhat less transparent than the surrounding sea water.

Chacko and Mathew (1956 a) recorded the eggs of this sardine from the plankton of the west coast and according to them the eggs are spherical with a diameter of 1.0 to 1.2 mm. They mention the presence of very wide perivitelline space even though the yolk measures 0.94 to 0.98 mm. in diameter. A small yellow oil globule measuring about 0.1 mm. is present in the yolk mass. Nair (1959) pointed out that the eggs and larvae of *S. albella* (Cuv. & Val.) described by Chacko and Mathew do not tally with those of the same species described by Delsman in the absence of the double egg membrane and the perivitelline space, the latter of which is apparent from the diameters of the egg and the yolk mass given by them, and also in the presence of larval pigmentation.

Newly Hatched Larva—According to Chacko and Mathew (1956 a) the newly hatched larva measures 2.1 to 2.3 mm. in length with 37 preanal and 3 postanal myotomes. A couple of hours after hatching the larva becomes straight and measures 2.5 mm. in length. The newly hatched larva figured by Delsman also measures 2 mm. in length.

One-day-old Larva—The one-day-old larva grows to a length of 4.2 mm. according to Chacko and Mathew and 3.9 mm. according to Delsman. In this stage the rudiment of the pectoral fin is seen and the vent is below the 37th myotome with 5 postanal myo tomes. Chacko and Mathew noticed a few yellow pigment cells in the head of the one-day-old larva whereas Delsman states that he could not discover any larval pigmentation although he observed scattered black pigment cells in the eggs. The larva is 4 mm. in length after 36 hours and the yolk is almost absent in this stage. A moderately developed pectoral fin is seen and the eyes are black in colour.

Two-day-old Larva—According to Chacko and Mathew, the two-day-old larva is 5.6 mm. in length with black eyes and the yolk almost completely absorbed. In the evening of the third day they observed the differentiation

of the caudal fin rays and the presence of brownish pigment cells along the lower side of the myotomes.

Adult

Growth and Longevity—There is very little information on the growth and longevity of this sardine and the observations made by Sekharan (1955) in the Palk Bay and the Gulf of Manaar on these aspects of *S. gibbosa* (Bleeker) are applicable to this species also since the *choodai* fishery is composed of these two species.

Food and Feeding Habits—The food of *S. albella* (Cuv. & Val.) occurring along the west coast has been worked out by John (1939), Chacko (1956) and Chacko and Mathew (1956 a). According to these authors, the sardine is a pure plankton feeder and *Coscinodiscus* and *Fragilaria* are constant items in their stomach contents. Among the zooplanktonic organisms copepods like *Paracalanus, Acartia, Oithona, Corycaeus* and *Euterpina* are seen in good quantities. Fish eggs and *Sagitta* formed frequent items of the diet of the fish. They also observed that the blue-green alga, *Trichodesmium* is found in fair quantities during the summer months April and May. Devanesan and Chidambaram (1948) observed that the sardines feed mainly on *Lucifer, Sagitta*, crab larvae and *Trichodesmium.*

The food and feeding habits of the sardine occurring on the Madras coast have been studied by Vijayaraghavan (1953). He found that the fish feeds chiefly on small crustaceans and on copepods belonging to the genera *Euterpina, Oithona, Pseudodiaptomus* and *Acartia.* He also found the presence of larger items of food like *Mesopodopsis, Lucifer, Acetes* and *Squilla* larvae. Based on this study extending for four months he concluded that *S. albella* (Cuv. & Val.) is essentially a surface filter-feeder capable of particulate feeding and showing a selective preference for crustacean food in general.

Bapat and Bal (1950) state that the post-larvae and juveniles of this sardine occurring in the Bombay waters are plankton feeders since copepods formed a high percentage of the stomach contents. They also observed crustacean and prawn remains, foraminiferans and sand grains in the stomach contents.

Sam Bennet (1961 b) also found that *S. albella* (Cuv. & Val.) is a plankton feeder and copepods formed the major item of food. The prevalence of larger forms like *Lucifer* and *Acetes* suggests that the fish is not an indiscriminate filter-feeder.

Population

Sex Ratio—Chacko and Mathew (1956 a) noticed the dominance of the females in the commercial catches of the west coast during most of the months of the year. They also found that in fully mature females the ovary occupies three-fourth of the visceral cavity while the testis fills only half the space in the case of males.

Age Composition—The age composition of this sardine occurring in the Palk Bay and the Gulf of Manaar is the same as that of *S. gibbosa* (Bleeker) (Sekharan, 1955, 1959).

Table 16 — Size Composition in Commercial Catches

Year	Months	Modes (cm.)
1952	April	3.7, 10.7
	May	4.7, 10.7
	June	5.2, 10.7
	July	6.7
	August	6.7
	September	7.2
	October	7.7
1953	March	10.7
	April	10.7
	May	4.2, 10.7
	June	6.7, 11.2
	July	7.2, 10.2
	August	8.2
	September	8.7
	October	9.2
	November	9.2
	December	9.7
1954	January	10.2
	February	10.7
	March	10.7

Size Composition—The analysis of the commercial catches of this sardin in the Palk Bay and the Gulf of Manaar was made by Sekharan (1955) and th monthly changes in size composition observed by him are given in Table 16

Sekharan (1959) later made a study of the dominant size groups of th sardine belonging to the 1952-1955 year classes at the time of their first entr in the catches made with the different types of tackle. He found that shore seines with increasing mesh size are used in the successive periods for the cap ture of *choodai* constituted by *S. albella* (Cuv. & Val.) and *S. gibbosa* (Bleeker and this is necessitated by the growth of the juveniles in the coastal waters He found that the shore-seine catches adequately sampled the stock o juveniles present in the region. His observations are tabulated below :

Nets	Year classes			
	1952	1953	1954	1955
Hand-net	3.0-3.4	...	2.5-2.9	3.5-3.9
Shore-seine	3.5-3.9	...	2.5-2.9	...
	5.0-5.4	4.0-4.4	4.0-4.4	4.5-4.9
	6.5-6.9	6.5-6.9	5.0-5.4	6.0-6.4
Boat-seine	...	6.0-6.4	6.0-6.4	7.0-7.4
Gill-net	...	9.0-9.4	7.0-7.4	7.5-7.9

Based on the length frequency studies on this sardine found on the west coast Chacko and Mathew (1956 a) stated that the 15-16 cm. size groups form the bulk of the commercial catches. They observed the entry of the 12 cm. size group into the population early in February. The largest sardine measuring 18 cm. are met with in February, April, June and November.

Predators—The sardine forms the food of carnivorous fishes like *Carcharhinus melanopterus* (Quoy & Gaim.), *Chirocentrus dorab* (Forsk.), *Sphyraena obtusata* Cuv., *Trichiurus savala* Cuv., *Eleutheronema tetradactylum* (Shaw) and *Lactarius lactarius* (Bl. & Schn.).

Parasites—Sam Bennet (1961 a) collected several females of *Peroderma cylindricum* Heller, some with eggs, from *S. albella* (Cuv. & Val.). This parasite shows a decided preference for this sardine. The entire trunk of the parasite is enclosed within the body of the host and the egg-tubes alone project outside. When the egg-tubes are not present, a small hole which is extremely difficult to locate shows the presence of the parasite. Generally a sardine is infested with a single parasite. The parasite penetrates the lateral muscle and reaches the posterior aorta near the kidneys where it is assured of a plentiful supply of blood.

Bomolochus sardinellae, parasitic on the eye-ball of this sardine has not been collected from any other fish of this locality, not even from *S. gibbosa* Bleeker) which commonly occurs along with this sardine. Usually a female with a male attached to its genital segment is found in each eye almost completely hidden beneath the adipose lid (Sam Bennet, 1964).

Sardinella fimbriata (Cuv. & Val.) (Fig. 15) syn. *Spratella fimbriata* Cuv. & Val., 1847; *Clupea fimbriata* (Part) Day, 1878, 1889; *C. (Harengula) fimbriata* Part) Weber & Beaufort, 1913; *Sardinella fimbriata* Regan, 1917, Fowler, 1941, Herre, 1953.

Bengali: *Khaira*; Telugu: *Noone-kavallu*; Tamil: *Sudai*; Malayalam: *Chalamathi*; Kannada: *Pedi, Erebai*; Marathi: *Pedwa, Washi*; Hindi: *Charreeiddee*.

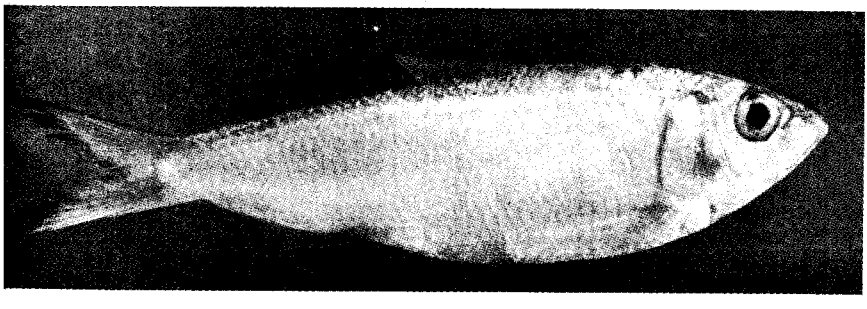


Fig. 15 — *Sardinella fimbriata* (Cuv. & Val.)

Description

Depth of body 3 to 3.5 in length, length of head 4. Snout as long as diameter of eye, which is 3.5 to 3.7 in length of head; maxillary extending to below anterior 0.3 of eye or a little beyond. 70-75 gill-rakers on lower part of anterior arch. About 45 scales in the longitudinal and 12 in a transverse series; ventral scutes 18-19+12-13. Dorsal 18-19. Anal 18-21. Pelvic 8-rayed, in advance of middle of dorsal. A dark spot at base of anterior dorsal rays; upper part of dorsal and posterior edge of caudal dusky (Regan, 1917).

Distribution

India, Malay Archipelago, Philippines, China.

Bionomics

Age and Size at Maturity

According to Chidambaram and Venkataraman (1946) this sardine attains a size of 15 cm. at first maturity along the west coast. Chacko (1956) found mature shoals of this sardine composed of specimens measuring from 12 to 16 cm. in the Tuticorin Bay and stated that the sardine attains maturity when it measures 12 cm. Dutt (1962) found that the sardines reach maturity when they are about 10 cm. along the Waltair coast. Radhakrishnan (1964) found that the smallest sardines with the ovaries in the spent condition were in the 14 to 15.9 cm. size groups and concluded that the sardines mature for the first time when they reach this size.

Spawning Season

The spawning season of the sardine along the Malabar coast extends from April to June (Chidambaram & Venkataraman, 1946). Chacko (1956) found that the spawning season in the Tuticorin Bay extends from October to November. He also observed the presence of mature individuals in October and spent ones in November.

Bapat (1955) observed that the eggs of *S. fimbriata* (Cuv. & Val.) are confined to the Gulf of Manaar region only while they are entirely absent in the Palk Bay. He observed the presence of eggs in the plankton during December to February in 1949-50 and during December, January and March in 1951-52. Apparently the spawning season of the sardine in the Gulf of Manaar is short and confined to the colder months of the year. Based on the gonadial studies, Radhakrishnan (1964) concluded that the spawning season is of short duration and commences in Karwar waters sometimes during the early part of the year.

Early Life-History

Egg—The early life-history of *S. fimbriata* (Cuv. & Val.) has been worked out by Delsman (1926 a) and Bapat (1955). According to Delsman the

eggs of the sardine are very common and sometimes occur in very large numbers in the Bay of Batavia where the adult is the most common sardine found in the catches. The egg measures 1.4-1.53 mm. in diameter with the yolk measuring about 0.8 mm. A small more or less yellow oil-globule is present which shows a diameter of 0.1 mm. Sometimes a second smaller oil-globule is also present. Delsman observed small scattered black pigment cells in the embryo. The eggs collected from the Gulf of Manaar by Bapat varied in diameter from 1.33 to 1.34 mm. The yolk is colourless, transparent and coarsely vacuolated. The embryo and the yolk occupy nearly half the egg capsule leaving a large perivitelline space. No pigmentation was observed by Bapat in the embryo.

Newly Hatched Larva—The newly hatched larva described by Delsman measures 2.58 mm. The vent is below the 40th myotome with 11 or 12 postanal muscle segments. The total myotome number present in the newly hatched larva is higher than the adult vertebral number which is 45-46 in *S. fimbriata* (Cuv. & Val.).

After 12 hours the larva measures 3.84 mm. The yolk is much smaller in size. The vent continues to be under the 40th myotome but Delsman noticed only 5 postanal myotomes in this stage. The rudiment of the pectoral fin is seen. A few faint pigment spots have appeared on the dorsal side behind the auditory vesicles and on the brain (Delsman, 1926 a).

According to Bapat (1955) the 18-hour-old larva measures 3.08 to 3.14 mm. with 38 to 39 preanal and 7 to 8 post-anal myotomes. He found the yolk-sac tapering posteriorly with the oil-globule situated in the anterior region. No pigmentation was observed by him in this stage.

One-day-old Larva—In the one-day-old larva the eyes get slightly pigmented and they are black in 1½ day-old larva. The yolk completely disappears in the latter stage (Delsman, 1926 a).

Two-day-old Larva—The two-day-old larva measures 4.15-4.25 mm. in length. The formation of the pectoral fins is seen as bud-like projections. The eyes get pigmented and streaks of pigment cells are found along the alimentary canal (Bapat, 1955).

The 2½ day-old larva measures 3.93 mm. and shows further development of the pectoral fin. Black pigment cells are found along the gut and the anus continues to be under the 40th myotome (Delsman, 1926 a).

Five-day-old Larva—The larva on the fifth day shows deep pigmentation of the eyes and the alimentary canal along its entire length.

Delsman (1926 a) described a few more clupeoid larvae collected with the plankton nets and stated that it is hardly possible to identify them owing to the small differences observed in the different types of larvae. He found that the position of the dorsal fin is completely different in all the larvae from that in the adult where it is above the ventral fins and a good distance in front of the anus. Since the position of the dorsal fin is an important character, the specific identification of the larvae was not attempted by him. However, he doubtfully referred three larvae to *S. fimbriata* (Cuv. & Val.). The first

larva measures 5.5 mm. in length and possess 39 preanal myotomes. He pointed out that this larva in spite of its large size is not much advanced in development than the 2½ day-old larva reared by him. He found that the myotomes are considerably broader and pigmentation somewhat distinct. A series of black pigment spots are found along the gut and the chromatophores are arranged above it in the anterior region and below it in the posterior region. The fin-fold is very narrow and indications of the formation of the dorsal and caudal rays are visible in this stage.

The other two larvae described by him measure 22 and 27.5 mm respectively. In these larvae all the fins are well-developed and show the normal number of rays. The dorsal and anal fins possess 19 rays. The shifting of the dorsal fin is seen in these stages and in the larger larva its anterior end is right above the ventral fins. He found in both the larvae 34 preanal myotomes. He also stated that the number of fin rays in the first rudiment of the dorsal fin is less than in the adult and that the number increases by the addition of new rays in the anterior end whereas in the anal fin new rays appear in the posterior end. He found the caudal fin formation on the upper side of the tail and thus it assumes a terminal position only afterwards.

Dharmamba (1963) pointed out that the juveniles of *S. fimbriata* (Cuv. & Val.) resemble closely *S. gibbosa* (Bleeker) in their morphometric characters. Study of meristic characters shows that the two species differ in the number of post-ventral scutes in addition to differences in the number of vertebrae, pectoral fin rays and gill-rakers. She pointed out the advantage of post-ventral scute number over gill-raker number for separating the two species. The number of post-ventral scutes does not vary with the size of the fish, and being an external character could be counted without difficulty. She has also observed that in juvenile *S. fimbriata* (Cuv. & Val.) the black chromatophores on the tongue are confined to the base or to one or two groups on the tongue besides those at the base, but never present all over the surface of the tongue as in *S. gibbosa* (Bleeker). This colouration according to her can be used for distinguishing the species in the field, as it can be quickly observed by opening the mouth of the fish wide.

Adult

Food and Feeding Habits—Chidambaram and Venkataraman (1946) stated that the food of this sardine occurring on the west coast consists of phytoplankton represented by *Coscinodiscus, Fragilaria, Nitzschia, Planktoniella, Pleurosigma, Thallassiothrix, Trichodesmium* and zooplanktonic constituents like *Acanthometron*, copepods, *Lucifer*, prawn and fish larvae.

In the Vellar estuary, Porto Novo, Chacko *et al.* (1954) found this sardine feeding on larval bivalves, *Acartia* and *Lucifer*.

Chacko (1956) made a general study of the food and feeding habits of different size classes of this sardine found in the Tuticorin Bay. He stated that the sardines measuring from 9.5 to 12.5 cm. found in April feed on copepods and diatoms like *Biddulphia, Coscinodiscus* and *Thallassiothrix*. The larger

size groups measuring 11.5-14.5 cm. seen in June showed more zooplanktonic food composed of copepods and their nauplii, *Dinophysis*, *Peridinium*, *Ceratium* and larval bivalves. Diatoms like *Coscinodiscus* and *Fragilaria* were also noticed in the stomach contents of these groups. In October the mature shoals composed of 12 to 16 cm. size groups again showed zooplanktonic dominance in their food which consisted chiefly of copepods, *Dinophysis*, larval bivalves and gastropods. The sardines measuring 14.5-16 cm. found in the fishery from January onwards showed their stomachs filled with copepods, *Peridinium*, *Biddulphia*, *Coscinodiscus*, *Fragilaria*, *Nitzschia*, *Pleurosigma* and *Thallassiothrix*.

Basheeruddin and Nayar (1961) found the juveniles occurring off Madras coast to feed predominantly on the phytoplanktonic organisms. A few copepods and other crustaceans were also observed in the diet of the juveniles.

Radhakrishnan (1964) found that the sardine feeds on both zoo- and phytoplankton in the Karwar waters. During the peak period of the fishery from September to November the food consisted mainly of items like *Acartia*, *Evadne*, *Penilia*, copepod eggs, *Coscinodiscus*, *Euterpina* and cypris larvae. December to March showed relative abundance of the zooplanktonic food. From April to August, phytoplankton predominated in the stomach contents, the commonest diatoms being *Coscinodiscus*, *Navicula*, *Nitzschia*, *Thallassiothrix* and also zooplanktonic forms like *Lucifer* and *Oithona*. Fish larvae were also recorded in the stomach of the sardine during September.

Population

Sex Ratio—In the Tuticorin Bay Chacko (1956) found that the sardines measuring 10.5 cm. in length found in the fishery in April showed the presence of gonads and among them the proportion of the males and females was found to be equal. But in June when the size composition increased from 11.5 to 14.5 cm. with the gonads in maturity stage III he found that the females are more in number than the males, the ratio being 6: 4. Almost equal proportion of the sexes is again noticed in October among the mature individuals measuring 12-16 cm. in length. He found that the males are double the number of females from January onwards when there is heavy shoaling of sardines measuring 14.5-16 cm. in length, with their gonads in maturity stages I and II.

Age Composition—Dutt (1962) observed that the juveniles of *S. fimbriata* (Cuv. & Val.) enter the inshore waters of Waltair coast in October and remain there up to May for a period of intensive feeding and growth. Towards the end of the fishery in May-June spent adults of 1 year class also enter the inshore waters for a short period. He also observed that shoals of *S. fimbriata* (Cuv. & Val.) and *S. gibbosa* (Bleeker) remain mostly discrete, although both species occur in the same region.

Radhakrishnan (1964) found that the fishery was mainly contributed by 1 plus group in Karwar waters.

Size Composition—Chacko (1956) observed that the shoals appearing in the Tuticorin Bay during April are composed of sardines measuring 9.5-12.5 cm. in length. By June the size range increased from 11.5-14.5 cm. In October the shoals are formed by sardines measuring 12-16 cm. In November he found the new recruits entering the fishery and the size range varying from 10-17.5 cm. Heavy shoaling of the sardine observed from January onwards is composed of 14.5-16 cm. size groups of sardines.

Sardinella sirm (Walbaum) (Fig. 16) syn. *Clupea sirm* Walbaum, 1792; Rüppell, 1835; *Sardinella leiogaster* Cuv. & Val., 1847; *Clupea leiogaster* Day, 1878, 1889; *C. (Amblygaster) leiogaster* Weber & Beaufort, 1913; *Sardinella sirm* Regan, 1917; Fowler, 1941; Herre, 1953.

Tamil: *Keerimeen chalai.*

Description

Depth of body 4.5 to 5 in length, length of head 4 to 4.5. Snout longer than diameter of eye, which is 3.7 to 4.3 in length of head; maxillary nearly or quite reaching vertical from the anterior margin of eye. 36 to 40 gill-rakers on lower part of anterior arch. 42 to 45 scales in a longitudinal, 12 in a transverse series; ventral scutes 16-18+13-15. Dorsal 17-19. Anal 17-20. Pelvics 8-rayed, in advance of middle of dorsal (Regan, 1917).

Distribution

East coast of Africa, Red Sea, Arabia, India, Malay Archipelago, Polynesia, Micronesia, Philippines, China.

Bionomics

Age and Size at Maturity

According to Gnanamekalai (1962 a) *S. sirm* (Walbaum) attains maturity when 14-15 cm. in total length. The growth in length is steady till 21 cm. when the fish spawns for a second time. The sardine reaches senescence and maximum size of 24-25 cm. in nearly $1\frac{1}{2}$ years.

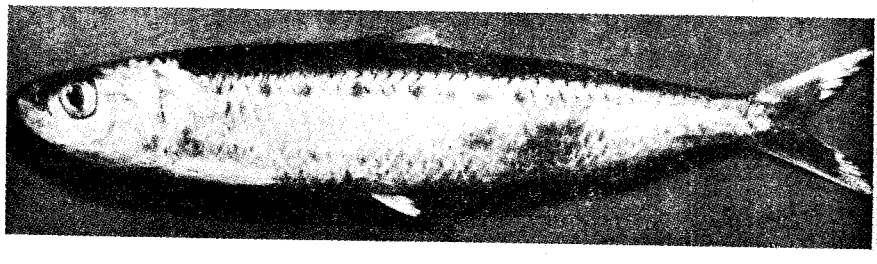


Fig. 16 — *Sardinella sirm* (Walbaum)

Spawning Season

There is one spawning period every three months in November-December and February-March during the fishery period and in May-June and August-September during the off-season.

Early Life-history

Egg—The early life-history of this sardine has been elucidated by Delsman (1926 a) and John (1951). The egg is perfectly spherical and according to Delsman the diameter of the egg varies from 1.42 to 1.63 mm. whereas John recorded a higher diameter of 2.12 mm. The yolk is segmented and devoid of oil-globules. The perivitelline space is fairly wide.

Newly Hatched Larva—The size of the newly hatched larvae recorded by Delsman and John does not agree. From the figure of the newly hatched larva given by Delsman it is found that it measures only 3.21 mm. while John records a length of 6.5 mm. According to John the larva possesses 37 (38 according to Delsman) preanal and 6 postanal myotomes including the unsegmented terminal portion of the tail. The muscle fibres show the usual crossed arrangement. The yolk mass is segmented and rounded at the posterior end. John observed the presence of certain black spots in the newly hatched larva of which the one at the tip of the upper jaw is believed by him to be characteristic of this stage only since it disappears during the same day. Minute stellate black chromatophores are found in the interorbital region and a row of very minute black dots along the alimentary canal. John also found a few black dots on the dorsal and ventral sides of the body at the region of the tail and considered this pigmentation as characteristic of the species. Delsman, on the other hand, does not record any pigmentation in the newly hatched larva, but states that pigment cells are present only after 12 hours. A comparison of the figures of the newly hatched larva given by Delsman and John shows differences in other characters as well. In the newly hatched larva John found the formation of the mouth as an antero-terminal slit and the rudiment of the pectoral fin as a clear circular structure. These characters have been observed by Delsman in the 12-hour-old larva only. The size of the yolk mass in the newly hatched larva figured by John is considerably smaller than that in the figure of the same stage given by Delsman. It is, therefore, likely that the larvae described by John are not the newly hatched ones but those after the lapse of several hours.

According to John the larvae after 12 hours do not show any appreciable change except in the slight reduction of the yolk mass. Delsman's figure of the same larval stage shows considerable increase in length and measures 4.11 mm.

One-day-old Larva—No increase in the length was noticed by John in the 24-hour-old larva while Delsman's figure of the same stage shows further increase and it measures 5.67 mm. According to John the mouth is well formed in this stage with a projecting lower jaw and the eyes become black in colour. Delsman noticed the first trace of darkening of the eyes after 24

hours and he found them to be black after 36 hours. John observed that th yolk is completely absorbed and the black spot at the tip of the upper ja disappears in this stage. He also found that the chromatophores along t alimentary canal are arranged on the dorsal side in the anterior half and the ventral side in the posterior half.

Three-day-old Larva—Delsman reared the larva up to the third day wh it measured 5 mm. thereby registering a decrease in length which is norma seen when the yolk is completely absorbed. He found that the vent is situat below the 37th myotome in this stage.

Adult

Growth and Longevity—Gnanamekalai (1962 a) found that the rate growth in *S. sirm* (Walbaum) averages 10-12 mm. a month and that there rapid growth of about 20-30 mm. in the month prior to spawning.

Food and Feeding Habits—According to Chacko (1956) the food consi mainly of copepods, nauplii and zoea larvae, larval bivalves and gastropo *Peridinium* and *Ceratium*. Basheeruddin and Nayar (1961) found the juvenil to feed on phytoplanktonic organisms, a few copepods, other sm crustaceans, and lamellibranch and gastropod larvae.

Population

There is very little information available about the other aspects of t biology of this sardine. According to Chacko (1956) this sardine contribut to a good fishery in the Tuticorin Bay from November to March and t catches are composed mainly of sardines measuring from 14.5 to 21.5 cm. length. In view of the absence of mature adults in the fishery, he suggest the possibility of the species breeding in the offshore regions. He found th the females were always more than the males, the ratio being 2: 1.

Abnormality—Gnanamekalai (1962 b) recorded an instance of gonadi abnormality in this sardine where the right ovary was totally absent and t left ovary occupied the entire abdominal cavity.

Sardinella melanura (Cuv.) syn. *Clupea melanura* Cuvier, 1829; *Clupeon commersoni* Cuv. & Val., 1847; *Clupea atricauda* Day, 1878, 1889; *C. (Hare gula) atricauda* Weber & Beaufort, 1913; *Sardinella melanura* Regan, 191 Fowler, 1941, Herre, 1953.

Tamil: *Kavalai.*

Description

Depth of body 3.5 to 4 in length, length of head 4 to 4.5. Snout as long a or a little longer than diameter of eye, which is 3.5 to 4 in the length of head maxillary extending to below 0.3 of eye. 38 to 44 gill-rakers on lower part o anterior arch. 44 to 46 scales in a longitudinal series; 12 or 13 in a transvers

series; ventral scutes sharply keeled, 19-20 + 13. Dorsal 18-19. Anal 16-18. Pelvics 8-rayed, below or a little in advance of middle of dorsal. A dark spot at base of anterior dorsal rays; ends of caudal lobes usually blackish (Regan, 1917).

Distribution

East coast of Africa, Madagascar, India, Malay Archipelago, Polynesia, Micronesia, Philippines, China.

Seasonal Variation

According to Vijayaraghavan (1953) this sardine occurs in Madras throughout the year except during December and January when stray numbers alone are present in the fishermen's catches. The juvenile sardines measuring from 5 to 13 cm. are common during July to September. The larger sardines measuring from 13 to 20 cm. are common during September and October and are also available in small numbers during the other months of the year.

Bionomics

Adult

Food and Feeding Habits—Vijayaraghavan (1953) observed some difference in the quality of food taken by the juveniles and the adults and stated that the smaller size groups are not capable of ingesting prey beyond a particular size. He found the juveniles feeding more frequently on the vegetable matter and small crustaceans mostly larval forms. The copepods also formed a good proportion of the food of the juveniles. The food of the adult sardines consisted chiefly of smaller crustaceans even though appreciable quantities of large-sized crustaceans like prawns, *Acetes* and *Mesopodopsis* are met with in the stomach contents frequently. Copepods like *Pseudodiaptomus*, *Paracalanus*, *Eucalanus* and *Corycaeus*, ostracods and larval forms of decapods appear to be the favourite food of the adults. The food of this sardine is mainly composed of zooplankton and he, therefore, suggested that it is a surface and plankton feeder. He pointed out that the quantity of the smaller organisms ingested indicates filter feeding while the occurrence of larger crustaceans is suggestive of particulate feeding.

Three more species of the genus *Sardinella*, namely *S. sindensis* (Day), *S. dayi* Regan and *S. clupeoides* (Bleeker) are recorded from Indian waters, but there is practically no information available about their biology and fishery. The synonyms, descriptions and distribution of these 3 species are included for information.

Sardinella sindensis (Day) syn. *Clupea sindensis* Day, 1878, 1889; *Sardinella sindensis* Regan, 1917; Fowler, 1941; Herre, 1953.

Description

Depth of body 3.25 to 4 in length; length of head 3.7 to 4.3. Snout as long as or shorter than diameter of eye, which is 3.5 to 3.75 in the length of head; maxillary extending to below anterior 0.3 of eye. 58-66 gill-rakers on lower part of anterior arch. 44-48 scales in a longitudinal, 11-13 in a transverse series; ventral scutes 17-19 + 12-15. Dorsal 17-19. Anal 18-21. Pelvics 8-rayed, below or in advance of middle of dorsal. A dark spot at base of anterior dorsal rays; upper part of the dorsal and ends of caudal lobes sometimes blackish (Regan, 1917).

Distribution

Zanzibar, Seychelles, India, Amboina, Philippines, Formosa.

Sardinella dayi Regan syn. *Sardinella dayi* Regan, 1917; Fowler, 1941.

Description

Depth of body 2.75 in the length, length of head 3.8. Snout as long as diameter of eye, which is 3.7 in length of head; maxillary extending to below anterior 0.3 of eye. 130 gill-rakers on lower part of anterior arch. 44 scales in a longitudinal and 12 in a transverse series; ventral scutes 19+13. Dorsal 18, nearly equidistant from end of snout and base of caudal. Anal 19. Pelvics 8-rayed, below middle of dorsal. Pectoral 0.75 in length of head. Silvery; back darker; a blackish spot at base of anterior dorsal rays; upper part of dorsal and edge of caudal dusky (Regan, 1917).

Distribution

Mauritius, India, Philippines.

Sardinella clupeoides (Bleeker) syn. *Amblygaster clupeoides* Bleeker, 1849; *Clupea clupeoides* Günther, 1868; *C. (Amblygaster) clupeoides* Weber & Beaufort, 1913; *Sardinella clupeoides* Regan, 1917; Fowler, 1941; Herre, 1953.

Description

Depth of body 3.75 to 4.5 in the length; length of head 4 to 4.5. Snout as long as or a little longer than diameter of eye, which is 3.5 to 4 in length of head; maxillary not extending to below eye. 27 to 31 gill-rakers on lower part of anterior arch. 42 to 44 scales in a longitudinal, 12 in a transverse series; ventral scutes 16-17 + 12-14. Dorsal 17-19. Anal 16-18. Pelvics 8-rayed, nearly below origin of dorsal (Regan, 1917).

Distribution

Red Sea, Ceylon, Malay Archipelago, India, Japan, Philippines.

Bionomics

Food and Feeding Habits—*Mysis*, Alima larva, Phyllosoma larva, juvenile *Porcellana* spp., *Thenus* early stage, *Acetes*, copepods and semi-digested fish tissue are the items recorded by Sam Bennet (1965) from the gut contents of *S. clupeoides* (Bleeker).

Dussumieria hasselti Bleeker (Fig. 17) syn. *Dussumieria hasselti* Bleeker, 1850; Day, 1878, 1889; Weber & Beaufort, 1913; Fowler, 1941; Herre, 1953.

Tamil: *Thondan, Modukandai*; Telugu: *Morava*; Malayalam: *Kolachi, Kolakoyan*; Kannada: *Kolu baige, Siriande, Mennethe.*

Description

Elongate, dorsal and ventral profile evenly convex. Height 4- about 5, head 3.7, eye about 4, 1.4 times in post-orbital part of head. Snout acute, about 0.3 longer than eye. Maxillary nearly reaching below front margin of eye. Jaws equal. Origin of dorsal more than diameter of eye, nearer to caudal than to snout. Origin of anal far behind dorsal, about as long as post-orbital part of head. Origin of ventrals below the middle of dorsal. Pectorals pointed, about as long as post-ocular part of head. Caudal deeply incised. Distinct teeth on jaws, palatines, pterygoids and tongue. Gill-rakers about 22-24, slightly longer than branchial filaments, about 0.75 of eye, spinous at the inner side. Scales very deciduous. Elongated scales in the axil of pectorals and ventrals. Upper half dark greenish, silvery below. A golden lateral band from opercle to caudal. Fins hyaline, distal part of caudal black. First ray of dorsal and pectorals with a dark spot (Weber & Beaufort, 1913).

Distribution

India, Burma, Malay Peninsula, Malay Archipelago, Formosa and Queensland.

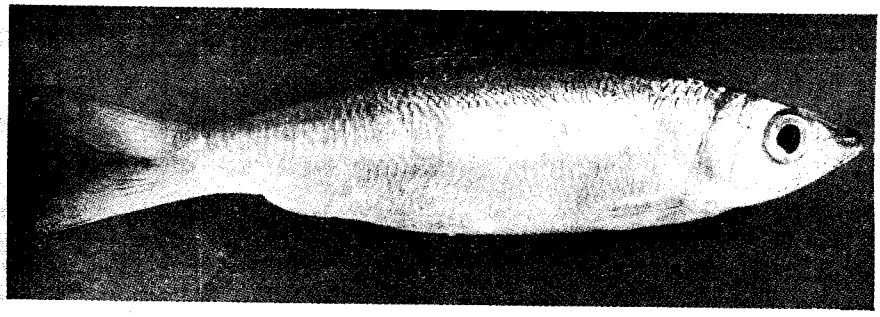


Fig. 17 — The Rainbow sardine, *Dussumieria hasselti* Bleeker

Seasonal Variation

The rainbow sardine contributes to a commercial fishery in the Gulf of Manaar and the Palk Bay and shoals in large numbers are encountered throughout the year with a peak period from May to October (Mahadevan & Chacko, 1962). It is not unusual to find in the catches other sardines like *S. albella* (Cuv. & Val.) and *S. gibbosa* (Bleeker).

Bionomics

Age and Size at Maturity

According to Devanesan and Chacko (1944) the commercial catches are mainly composed of sardines measuring 13 to 15 cm. and no younger specimens measuring less than 9 cm. have been collected by them. They state that the sexual maturity is attained for the first time when the fish measures 14 cm. in length. Mahadevan and Chacko (1962) found that the spawners are in the 12-13 cm. size groups and according to them the fish spawns before it is one year old.

Fecundity

The right ovary is long and pear-shaped while the left is very short. The testes which are thin whitish structures also show asymmetrical development with the right one placed far forwards and the left one far behind in the abdominal cavity. In both the sexes the right ovary and testis are fully formed while the left gonads are smaller in size. According to Devanesan and Chacko (1944) the right ovary of the rainbow sardine contains from 420 to 500 eggs, and the left ovary from 25 to 80 eggs. They found that all the ovarian eggs do not ripen at the same time and about 50 to 100 only become mature and transparent at a time. Several weeks elapse before all the eggs are discharged at intervals. According to them, the mature ovarian eggs measure 0.84 mm. in diameter. Mahadevan and Chacko (1962) on the other hand counted nearly 300 ripe eggs with a diameter of 0.99 mm. from the ovary of about fifty per cent of the fishes examined by them while the rest showed lesser number of ova in the same state of maturity. They also observed that on an average there are more than 5,000 eggs of all sizes in the right ovary alone.

Spawning Season

Based on the study of the rainbow sardines of the Palk Bay and the Gulf of Manaar, Devanesan and Chacko (1944) concluded that March to December constitute roughly the breeding season. They obtained specimens with fairly mature and transparent ovarian eggs in April, June, September and October and specimens partly or fully spent in April, May, July, September and November. Chacko (1950) also states that the spawning season is from March to December. Mahadevan and Chacko (1962) have contradicted the observations of the earlier authors and state that the spawning season of this sardine is from October to March in the Palk Bay and the Gulf of Manaar.

Consequently the breeding season of the rainbow sardine remains to be determined accurately. It may be mentioned here that post-larvae of *D. hasselti* (Bleeker) are recorded from the Trivandrum coast during February (Gopinath, 1946) and from Madras coast from March to June and in December (Basheeruddin & Nayar, 1961).

Early Life-history

Egg—Quite a few authors have studied the planktonic eggs and larval development of the rainbow sardine, but unfortunately their accounts do not tally and consequently it is difficult to identify the eggs and larvae of the rainbow sardine based on these earlier accounts. However, a complete account of the life-history as described by these authors is given here.

Delsman as early as 1925 studied the embryonic and larval history of this sardine and he found that the eggs are fairly regularly met with in the surface plankton of the Java Seas. The diameter of the planktonic egg varies from 1.45 to 1.55 mm. The egg membrane is smooth and the yolk is segmented and frothy in the characteristic clupeoid fashion. There is a small colourless oil-globule at the vegetative pole. He also observed that the development of the egg is completed in one and half days.

According to Devanesan and Chacko (1944) the planktonic eggs measure only 0.88 mm. in diameter with a clear and frothy yolk provided with a single yellow oil-globule measuring 0.26 mm. in diameter at the vegetative pole. It is seen that this description differs from that given by Delsman both in the size of the egg and the oil-globule. The oil-globule according to Devanesan and Chacko is nearly a third of the diameter of the egg.

Chacko (1950) in his account of the fish eggs found in the seas around the Krusadai Island gives 0.88 mm. as the diameter of the planktonic eggs of *D. hasselti* (Bleeker) but records a small colourless oil-globule at the vegetative pole. Bapat (1955) provisionally refers Egg Type G collected by him from the Gulf of Manaar and the Palk Bay to *Dussumieria* sp. The eggs are spherical and measure 1.41 to 1.67 mm. in diameter. The yolk is colourless, transparent and minutely vacuolated and almost fills the egg-capsule leaving a narrow perivitelline space. A single colourless oil-globule measuring 0.113 to 0.182 mm. is found near the vegetative pole. The embryo, yolk and oil-globule are devoid of pigment cells. Mahadevan and Chacko (1962) state that the eggs of the rainbow sardine collected from the Gulf of Manaar are spherical in shape measuring 1.0 to 1.15 mm. in diameter. One oil-globule measuring 0.26 mm. in diameter is observed by them. The egg membrane is smooth with a very clear narrow perivitelline space.

It is clear that two types of eggs have been attributed to the rainbow sardine by the earlier workers. A large egg with small oil-globule (Delsman, 1925 & Bapat, 1955) and a small egg with large oil-globule (Devanesan & Chacko, 1944; Chacko, 1950 and Mahadevan & Chacko, 1962). The latter authors found very little difference in size between the ovarian eggs and the planktonic eggs. With our present knowledge it is extremely difficult to say whether

these two types of eggs belong to the two species of *Dussumieria* and this task is rendered more difficult by the recent systematists recognizing only one species of rainbow sardine.

Newly Hatched Larva—Delsman (1925) found that the newly hatched larva shows the typical clupeoid characters namely, the backward position of the anus which is under the 50th myotome, segmented yolk and the characteristic crossed arrangement of the muscle fibres of the myotomes. The head of the larva is closely applied to the yolk. The eyes are unpigmented and some distance behind them are the auditory vesicles. Fine black pigment spots are scattered along the myotomes and on the upper surface of the head. The oil-globule occupies the posterior part of the yolk. There is considerable lengthening of the larva during the first few hours and in a nine-hour-old larva the myotomes are distinct and Delsman counted in one specimen 50 and in two specimens 49 preanal myotomes and 5 or 6 postanal myotomes. Rapid changes in the head of the larva take place and in the 18½-hour-old larva the first gill opening is seen below the auditory vesicle while the rudiment of the second gill opening is seen behind it. The small pigment spots have spread all over the surface of the yolk and along the gut, but have disappeared from the dorsal finfold.

According to Devanesan and Chacko (1944) the newly hatched larva measures 1.7 mm. in length. They also observed the conspicuous clupeoid characters namely the backward position of the anus under the 48th myotome, the vacuolated yolk, crossed arrangement of the muscle fibres and the yolk tapering into the gut posteriorly. They found 48 preanal and 9 postanal myotomes. The eyes are unpigmented and two rows of brown pigments are present on either side of the larva. One hour after hatching the larva becomes straight and measures 1.86 mm. in length. Three hours after hatching the larva is 1.92 mm. long with the anus showing a slight forward shift in position with 46 preanal and 11 postanal myotomes. The rudiments of the pectoral fins are seen. There is some change in the pigmentation and a patch of brown chromatophores at the anterior portion of the dorsal finfold and three branched chromatophores at the hind end of the yolk mass have appeared. After 4 hours the larva has grown to 2.14 mm. in length with a diminishing and posteriorly tapering yolk mass. The anus has shifted further forwards and is below the 45th myotome. The oil-globule has broken up into seven smaller ones each measuring 0.04 mm. in diameter but they remain collected together at the posterior portion of the yolk mass. Six hours after hatching the length of the larva is 2.70 mm. and fin-rays have appeared in the caudal region. There are 44 preanal and 13 postanal myotomes. Additional chromatophores have appeared around the anus. Eighteen hours after hatching the larva has increased in length to 3 mm. The yolk mass is reduced in size and the oil-globules break up into smaller ones before final disappearance. Fin-rays have appeared all along the finfold which has differentiated posteriorly into the caudal fin. The anus in this stage is below the 41st myotome.

According to Chacko (1950) the anus of the larva is under 45-48th myotome and he observed fine black pigment spots scattered along the myotomes. The ten-hour-old larva described by Bapat (1955) measures 5 mm. in length. The yolk-sac tapers posteriorly with the oil-gobule at the far end. He found the anus below the 48th myotome with four postanal myotomes. The larva possesses melanophores on the head and along the body above the alimentary canal. Mahadevan and Chacko (1962) found the hatchlings measure 1.8 mm. in length with 42 preanal and 10 postanal myotomes. Six hours after hatching fin rays appeared in the caudal region of the finfold.

One-day-old Larva—Devanesan and Chacko (1944) found that the one-day-old larva measures 3.12 mm. in length with the yolk mass further reduced in size. The otocysts have become larger and the rudiments of the lower jaw appear in this stage. After 27 hours, the length of the larva increases to 3.24 mm. Two gill-slits have appeared and the upper jaw is also differentiated. The anus has moved forwards with 39 preanal and 18 postanal myotomes. The eyes are unpigmented. Forty-five hours after hatching the larva measures 3.28 mm. and swims very actively at the surface with the help of the pectoral fins which are well developed. The yolk has completely disappeared and the mouth is wide open. The eyes are pigmented black and bluish green. The pigmentation of the finfolds also disappeared and there are now two rows of black pigment cells on the sides of the larva.

Mahadevan and Chacko (1962) found the yolk-sac completely absorbed after 32 hours when the larva measures 3.4 mm. in length. They found 48 preanal and 7 postanal myotomes.

Two-day-old Larva—Delsman (1925) found in the 48-hour-old larva all the gill-slits broken through with very wide openings. The lower jaw is well developed and the rudiments of the teeth begin to appear. The yolk which reaches up to the 26th myotome in the nine-hour-old larva and up to 20th myotome in the one-day-old larva has nearly been absorbed in this stage. There are 48 preanal myotomes. A few scattered pigment spots are present in the anterior half of the dorsal fin-fold. In the older larvae, immediately in front of the pectoral fin is a typical pigment spot and two small pigment spots are found invariably on the dorsal side of the head between the eyes. This pair of pigment cells may be seen in much older stages. The most striking feature of the head of the larvae of the rainbow sardine is the wide gaping mouth with the pointed jaws and the strongly developed teeth. In this respect the larvae resemble the eel larvae. Apart from these characters the larvae could be easily distinguished from the other clupeoid larvae by the elongated slender appearance and transparency (Delsman, 1925).

Devanesan and Chacko (1944) found the 53-hour-old larva measuring 3.46 mm. in length. They also observed the possession of a wide mouth showing strong dentition on the lower jaw. They found three gill-slits in this stage with clear pigmented eyes. They summed up the characters of the rainbow sardine as follows: the backward position of the anus and its subsequent movement forwards, the crossed arrangement of its muscles and the coinci-

dence of the complete using up of the yolk and the eyes becoming pigmented. The single oil-globule disappears by breaking up into smaller ones. The larva possesses a wide and gaping mouth with strong dentition.

Delsman (1925) also found that the yolk is absorbed in about $2\frac{1}{2}$ days when the eyes become black, but he could not keep the larvae alive for more than three days. However, he described a few advanced stages in the development of this rainbow sardine obtained from the plankton collections.

Delsman (1925) found in a 9.5 mm. larva a number of regularly arranged black spots along the under side of the gut and a similar series along the upper half of the myotome. In a 23 mm. larva a number of small pigment spots have appeared along the underside of the gut in between the larger ones already present in the larva. Laterally, the same regularly arranged pigment spots found in the earlier stages are present on the myotomes. In the 36 mm. larva this series of black pigment spots on the myotomes is still present while in the larva measuring 42 mm. and above they disappear completely. New pigment spots appear on the underside of the tail especially behind the anal fin. A few pigment spots appear at the base of the tail as well as on the tail fin.

Adult

Growth and Longevity—Mahadevan and Chacko (1962) studied the progression of the age groups through the fishery over a period of one year by studying the length frequencies of the commercial catches. They found that the fishery is mainly composed of sardines belonging to 10-13 cm. size groups which come under the 0-year class. Fishes more than 13 cm. in size do not enter the fishery and seem to disappear or die. The length frequency studies show that the species grows to 12-13 cm. in the first year itself.

Food and Feeding Habits—Devanesan and Chacko (1944) found that the diet of this sardine consists mainly of plankton and occasionally the fingerlings of the whitebait, *Stolephorus* sp. The following organisms are recorded by them in the stomach contents: *Zooplankton*: Copepods consisting chiefly of *Paracalanus* sp., *Acartia* sp., and *Oithona* sp., *Rhopalophthalmus egregius*, *Lucifer hanseni*, crab zoea and Megalopa larvae, larvae of *Squilla*, *Acetes* sp., *Creseis acicula*, *Spiratella* spp., larval bivalves and *Sagitta* sp.

Phytoplankton: *Coscinodiscus* chiefly *C. jonesianus*, *C. nobilis*, *C. oculusiridis* and *C. gigas* var. *dioramma*, *Rhizosolenia*, *Thallassiothrix*, *Trichodesmium* and algal filaments.

Chacko (1949) examined several specimens ranging in size from 9 to 20 cm. and stated that the sardine is a plankton feeder consuming mainly *Coscinodiscus*, *Rhizosolenia*, *Thallassiothrix*, *Trichodesmium*, copepods, *Rhopalophthalmus*, *Lucifer*, larval bivalves and *Sagitta* spp.

Mahadevan and Chacko (1962) studied the food habits of this sardine and found that the fish subsists entirely on planktonic organisms; diatoms, stomatopods, prawn larvae and copepods are the important items in the dietary of the fish. A systematic study of the feeding habits shows that the percentage

of empty stomachs is low from September to April and high in the following months thereby showing changes in the feeding activity during the year. The maximum feeding is in March and in November-December. The high rate of feeding seen in March is due to the consumption of copepods, larval prawns and stomatopods which are abundant in the plankton during that month. The rate of feeding is low and poor from April to August when diatoms constitute the chief item of food without appreciably increasing the volume of the stomach contents. This is due to the phytoplankton abundance during this period. These observations indicate that the intake of food is in consonance with the prevailing planktonic composition and according to these authors the trend of feeding may be considered as seasonal rather than in accordance with the size of the fish.

Population

Sex Ratio—The sex ratio of males and females in the commercial catches is about 1:2 (Mahadevan & Chacko, 1962).

Predators—Specimens of this sardine have been recorded from the stomach contents of the following fishes: *Chirocentrus dorab*, *Scomberomorus commersoni*, *Lactarius lactarius* and *Sciaena albida*. These fishes follow the shoals of rainbow sardines and feed on them (Devanesan & Chacko, 1944).

Parasites—The copepod parasites *Nothobomolochus multispinosus* (Gnanamuthu), *Clavellisa dussumieriae* Gnanamuthu and *Pseudopetalus dussumieri* (Rangnekar) have been recorded from the gill-rakers, gill arches, branchial cavity and buccal cavity (Pillai, 1967).

Abnormalities—Recently (Nair, 1970) collected a specimen of *D. hasselti* (Bleeker) in which both the ventral fins are absent and the abnormality is not attributed by him to any external physical injury.

FISHERY

Exploitation

The inshore waters of Rameswaram Island appear to be the favourite shoaling grounds of this rainbow sardine. The region from Kundukal point to Dhanushkodi affords excellent facilities for operating the shore-seines locally known as *Karai valai*. On the other side of this Island in the Palk Bay the fish shoals in the offshore regions of Thangachimadam and Rameswaram and in this region it is caught with the gill-net (*Kolavalai*) and bag-seine-net (*Madivalai*). The sardine contributes to a very important fishery around Rameswaram Island with average annual landings of 75 tonnes. In the fishing centres of Ramnad district the catches are dried on the beach without salt and exported to Ceylon where there is great demand for the cured sardine. In the west coast the fish is caught in the boat-seine (*Paithuvala*) and salted extensively and sent to Kolar where it is highly priced (Devanesan & Chidambaram, 1948; Mahadevan & Chacko, 1962).

Dussumieria acuta Cuv. & Val. syn. *Dussumieria acuta* Cuv. & Val., 1847; Günther 1868; Day, 1878, 1889; Weber & Beaufort, 1913; Fowler, 1941; Herre, 1953; *D. elopsoides* Bleeker, 1849.

Common Indian names are same as those of *D. hasselti* (Bleeker).

Description

Elongate, dorsal and ventral profile evenly convex. Height 4-4.5, head about 4, eye 3-nearly 4, 1.3 times in postorbital part of head. Snout acute, about 0.25 longer than eye. Fronto-rostral line straight. Maxillary not reaching below front margin of eye. Jaws equal. Origin of dorsal more than diameter of eye, nearer to caudal than to snout. Origin of anal far behind dorsal, about as long as postorbital part of head, shorter than ventrals, the origin of which is below the middle of the dorsal. Pectorals pointed, as long as head without snout. Caudal deeply incised, about 4 times in length. Distinct teeth on jaws, palatines, pterygoids and tongue, gill-rakers about 20, with very fine spines along the inner side, as long as pupil, slightly longer than branchial filaments. Scales thin, very deciduous, longitudinally striated, their hind margin rough or indistinctly crenulated. Elongated scales in the axil of pectorals and ventrals. Upper half dark greenish, lower half silvery. A golden lateral band from opercle to caudal. Fins hyaline, caudal with a dark margin. First ray of dorsal and pectorals with a dark spot (Weber & Beaufort, 1913).

Distribution

South Arabia, India, Ceylon, Malay Peninsula, Malay Archipelago, China, Philippines.

Bionomics

Early Life-history

Egg—Kuthalingam (1961) gave an account of the life-history together with the feeding habits of the larvae, juveniles and adults. He collected a number of eggs of *D. acuta* Cuv. & Val. from the tow-net collections made in the offshore regions about 40 km. north-east of the Madras harbour. It is extremely interesting that he reared them to the juvenile stages in the laboratory without any difficulty when the other workers under similar conditions have failed to rear them beyond the third day. He found that the eggs are perfectly transparent and spherical with an average diameter of 1.4 mm. The yolk is opaque, segmented and provided with a colourless oil-globule situated at the tail portion of the embryo. He found that the spherical eggs became irregular as development advanced and the embryo became fully developed.

Newly-Hatched Larva—The newly hatched larvae are transparent and float with the head downwards and measure about 2.6 mm. The eyes are unpigmented and the auditory vesicles and the vent are clearly seen. There are 49 preanal myotomes and 8 postanal myotomes with muscles showing the

typical clupeid arrangement. The oil-globule occupies the centre of the segmented yolk mass. A number of fine black pigment spots is present on the unpaired dorsal and ventral finfolds. Black patches are present between the eyes and the auditory vesicles.

One-day-old Larva—The larva continues to be transparent and swims in a serpentine manner and measures 3.1 mm. in length. The mouth is not developed and the yolk-sac is smaller in size with the oil-globule occupying the posterior end of the yolk mass. The auditory vesicle has become larger and the eyes continue to be unpigmented. The pectoral fin rudiment is seen as a prominent membranous fold. The anus has shifted forwards and there are only 47 preanal myotomes present in this stage. There was no change in the larva during the next day except its growth and the reduction in the yolk mass.

Three-day-old Larva—The larva is transparent and measures 7.2 mm. The yolk-sac is completely absorbed and the eyes have become black. The auditory vesicles have enlarged and the four gills are seen in this stage. The mouth and the alimentary canal are well defined. There is no change in the myotome number. The pectoral fins have slightly enlarged and appear fan-shaped without fin rays.

Kuthalingam found mortality of the larvae during the transition from the pro-larval to the post-larval phase and the reason for the same has not been determined even though he had stated that it was not due to lack of food or any change in the physical or chemical composition of the sea-water. He fed the older larvae with fresh concentrated plankton and found active feeding in almost all of them. He found them to feed exclusively on diatoms and filamentous algae rejecting all the other items of food present in the plankton. His laboratory experiments showed that they are strictly herbivorous feeding mainly on diatoms and pieces of sea-weeds.

Twelve-day-old Larva—The larva in this stage continues to be transparent and measures 14.2 mm. in length. The head is distinct and the mouth is well defined. There are 46 preanal and 11 postanal myotomes. The gills are well developed and rudiments of teeth are seen in this stage. The pigmentation of the dorsal side is very faint while that of the ventral side has disappeared completely. Two groups of black pigment patches, one above the eye and the other above the auditory vesicles are seen. Fin rays are well developed in the caudal region.

Twenty-one-day-old Larva—The larva measures 20.2 mm. in length with 44 preanal and 13 postanal myotomes. The pectoral fins are well formed and fin rays have appeared in the dorsal and anal fin regions of the finfold. The faint black pigment spots seen on the dorsal finfold have completely disappeared in this stage and dark black pigment patches are seen on the head.

Kuthalingam found a change in the food habits of the 21-day-old larvae and when fresh concentrated plankton was supplied to them, they fed on copepods, cirripede nauplii, molluscan larvae and polychaetes, both larvae and adults. Diatoms which formed the main food of the larvae till now

were totally avoided from the 21st day. The larvae continued on this diet for another ten days.

Thirty-two-day-old Larva—The post-larva measures 28.8 mm. and shows all the general characteristics of the species. The dorsal and anal fins have developed fin rays and the ventral fin appears as a flap. The caudal fin is deeply forked. The eyes are silvery in colour. The anterior region of the alimentary canal is straight and narrow while the posterior region is considerably enlarged. The larva has become less transparent and the myotomes are not distinct. Minute black pigment spots have appeared on the sides of the body.

Feeding experiments with these larvae showed that they feed on a variety of animals such as adult copepods, cirripede larvae, polychaetes, molluscan larvae, *Noctiluca*, *Sagitta*, megalopa and zoea of *Metapenaeus* and Brachyura and *Appendicularia*. Diatoms were found to be totally absent. Copepods rank as the main item of food constituting 48 per cent of the total volume of food. The common copepods are *Oithona*, *Corycaeus*, *Acartia*, *Pontella*, *Pseudodiaptomus*, *Macrosetella gracilis*, *Euterpina*, *Acrocalanus* and *Eucalanus*. There was no change in the feeding habit of the larva for six days.

Thirty-nine-day-old Larva—The post-larva measures 33.3 mm. in length without any change in the external features. The larva is opaque with black pigment patches on the head and a row of pigment cells on either side of the body. The dorsal and anal fins are extremely soft and transparent. Pectoral fins are well developed.

The post-larva in this stage feeds mainly on the adult copepods and diatoms and filaments of *Cladomorpha*. The inclusion of vegetable matter once again in the diet of the post-larva is noteworthy. There was no change in the diet for another 16 days.

Fifty-six-day-old Larva—The post-larva in this stage measures 48.2 mm. in length. These young fishes have a beautiful green colour with light blue shade along the upper margin of the opercle and along the back of the body. The caudal fin is blue-green and golden in colour and the upper surface of the head and eyes is emerald green. The pectoral, ventral and anal fins are white and almost transparent. Feeding experiments on the juveniles showed that they feed on a wide size range of animals. Copepods, *Lucifer*, *Squilla* larva, *Acetes* larvae, young ones of *Penaeus* sp., molluscan larvae, polychaetes, cirripede larvae, ostracods and zoea and megalopa stages of crabs were found in the stomach.

Adult

Food and Feeding Habits—Sekharan (1949) made a detailed study of the fluctuations in the fat contents of *D. acuta* Cuv. & Val. in relation to the feeding habits and maturity of the fish. He found that the fat deposition takes place during three different periods of the year namely August to October, November to March and April to July. During the first period the gonads

are quiescent, with the result the muscle fats are not withdrawn for their ripening. On the other hand, there are positive agencies namely the high rate of feeding especially on the crustaceans and teleosts which contribute to a great increase in the muscle fats. As teleosts are seen in the stomach of the fishes in large numbers and fat content of the fish is highest during this period it is presumed that the teleostean items of the diet are directly responsible for the fattening of the fish. This is clear from the next period when teleosts register a fall, the other constituents remaining the same, the fishes appear poorer in fat. It is also noteworthy that the crustaceans in the diet continue to be as in the previous months and even show an increase in December without any appreciable effect on the storage of fat. The fact that the teleosts are responsible for increase of the fat content of the fish is evident in the third period when the teleostean items of the food show an increase and the fat content of the fish also increases. Moreover, during this period the gonads receive no fat for their development and thereby the drain on fat tissues is greatly reduced.

Vijayaraghavan (1951) gave a descriptive account of the food of *D. acuta* Cuv. & Val. based on a volumetric analysis of the stomach contents and also the fluctuations of the chief items in the diet in relation to the growth of the fish. For this purpose he divided the fishes examined into two groups, the 13 cm. size group which includes all those measuring 13 cm. and above and the 10 cm. size group which includes all those measuring below 13 cm. He found that the 10 cm. size group subsisted chiefly on crustacea and a steady increase in the amount of crustacea consumed was noted from July to October. Crustaceans formed the major item of diet for the 13 cm. size group from January onwards. Thereafter there is a fall in the rate of feeding till March when once again increase in teleostean and crustacean items of food is found probably suggestive of the growth of the fish into the next size. He concluded that the fluctuations in the rate of feeding of the fish are probably correlated with its growth and that these are not influenced by the fluctuations in its favourite items of diet occurring in the environment.

Kuthalingam (1961) found that the fish feeds on a variety of planktonic animals. He also found that the diet of the young adult fishes measuring 60 to 80 mm. did not include diatoms whereas the older and larger ones showed high percentage of diatoms in the stomach. The largest fishes also had diatoms and their prey were larger in size. The absence of the diatoms in the smaller fishes is attributed by him to the poorly developed gill-rakers of the young fishes and not due to any deliberate choice or changeover to a mixed diet.

Parasites—Gnanamuthu (1950) noted the occurrence of females of a copepod parasite, *Parapetalus caudatus* Gnanamuthu in the posterior region of the floor of the mouth of *D. acuta* Cuv. & Val. obtained from the Madras coast. The cephalothorax of the parasite was found fixed near the posterior angle of the triangular mouth floor with the rest of its large flat body extending over the gill-arches. *Nothobomolochus multispinosus* (Gnanamuthu),

Bomolochus acuta Gnanamuthu, *Pseudopetalus dussumieri* (Rangnekar) and *Lernanthropus dussumieria* Gnanamuthu are the other copepod parasites recorded from the buccal cavity, branchial cavity and gills of this rainbow sardine (Pillai, 1967).

Kowala coval (Cuv.) (Fig. 18) syn. *Clupea coval* Cuv., 1829; *Kowala thoracata* Cuv. & Val., 1847; *Meletta lile* Cuv. & Val., 1847; *Clupea lile* Günther, 1868; Day, 1878 & 1889; *Clupeoides lile* Weber & Beaufort, 1913; *Clupea (Harengula) thoracata* Weber & Beaufort, 1913; *Kowala coval* Fowler, 1941.

Malayalam: *Chooda, Veloori*; Kannada: *Swadi balanjil*; Marathi: *Bhitgi.*

Description

Depth 2.75 to 3; head 4 to 4.25. Snout 3.8 in head from snout tip; eye 3 to 4.25, larger than snout, with broad adipose lids; maxillary reaches about 0.2 in eye, length 1.9 in head from snout tip; teeth on vomer, palatines, pterygoids and tongue; interorbital low. Gill-rakers about 32, somewhat longer than gill filaments, shorter than half of eye. Scales 38-41 in medial lateral series; 10 or 11 transversely; firm, smooth, border rounded and irregularly crenulated. About 16 pre-dorsal bony scutes (shown by Regan to be ends of supraneural bones projecting); ventral scutes 19 + 10. Dorsal III, 12, or 13, first branched ray 1.5 in total head length. Anal III, 14 to 16, first branched ray 2.5, caudal 3.9 in rest of body, well forked; least depth of caudal peduncle 2 in head; pectoral 1.25; ventral 1.9. Yellowish. Head, abdomen and median lateral band silvery. Two rows of black dots along back. Black dots on end of snout, top of head and in a row along each side of base of anal. Caudal dotted with black, dots more crowded at margin (Fowler, 1941).

Distribution

India, Pakistan, Ceylon, Burma, Malaya, Malay Archipelago and China.

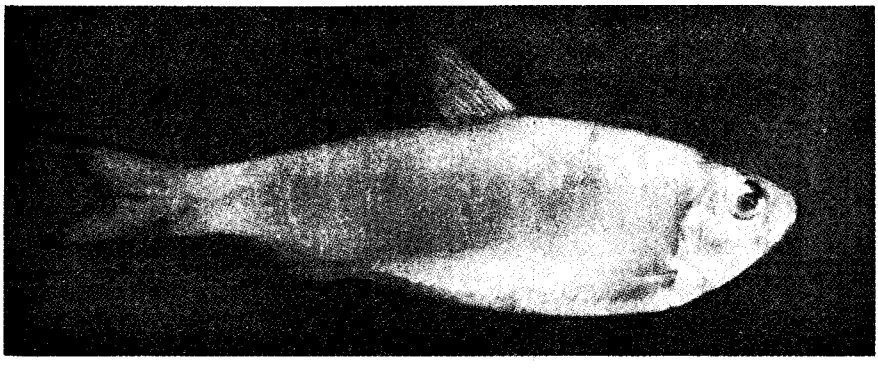


Fig. 18 — The White sardine, *Kowala coval* (Cuvier)

Differential Distribution

The white sardine, considered by Day, as an inhabitant of the west coast has been collected in swarms from the Canning river on the east coast by Mookerjee and Bhattacharya (1950). It is not available in the river throughout the year and its availability is restricted to April to October. It migrates into the river in younger stages and after attaining a considerable size returns again to the sea.

Nair (1951 a) found that the smaller fish usually enter the fishery by May and a gradual increase in their number is seen up to August when the maximum number occurs in the fishing area off Kozhikode. Their complete disappearance from the foreshore waters in the succeeding months is mainly due to certain environmental factors caused by the south-west monsoon. The intensification of the monsoon in June and July results in the formation of 'mud banks' in the foreshore areas when the sea-water becomes heavily laden with fine mud which gradually settles down after the cessation of the monsoon. This is followed immediately by the occurrence of swarms of *Noctiluca* imparting a red colour to the sea-water to constitute the 'red water phenomenon' which is known to affect adversely the general fishery conditions. These factors particularly affect the post-larval and juvenile fishes which completely disappear from the foreshore waters during the August-October post-monsoon period. The repopulation of the area by these fish is gradual depending on the species. Though the white sardine fishery commences immediately after the monsoon, the juveniles take a much longer time to enter the foreshore waters.

Annual Variation

The white sardine is a shoaling species inhabiting the shallow coastal waters and supports an important fishery along the west coast of India. It is one of the few economically important clupeoid fishes, the fisheries of which have assumed importance during the forties owing to the decline of the valuable oil sardine fishery. The fisheries of the white sardine and the lesser sardines were almost neglected in the former years when the oil sardines occurred in plenty (Nair, 1951 a & b). The estimated catch statistics of the white sardine from the South Kanara and Malabar coasts for the seasons 1925-26 to 1949-50 are given in Table 17.

The annual landings show a fluctuating tendency. The average annual landings for the entire period is about 606 tonnes and the landings were more than 1000 tonnes during five seasons while in some years the catches were relatively poor and less than 200 tonnes during four seasons. Though the annual landings varied from about 1411 tonnes in 1926-27 to about 88 tonnes in 1935-36, an irregular annual fluctuation of abundance at intervals ranging from one to three years is seen. The white sardine fishery showed a steady improvement in the later years and this is partly due to the increased exploitation consequent on the complete failure of the oil sardine fishery Nair, 1951a).

Table 17 — Estimated Catch of the White Sardine from S. Kanara and Malabar Coasts

Seasons	Landings (in tonnes)
1925-26	861.92
1926-27	1411.37
1927-28	307.98
1928-29	314.07
1929-30	242.85
1930-31	769.40
1931-32	159.91
1932-33	764.36
1933-34	810.96
1934-35	169.32
1935-36	87.96
1936-37	99.68
1937-38	1001.63
1938-39	365.25
1939-40	592.62
1940-41	814.88
1941-42	538.40
1942-43	365.48
1943-44	570.70
1944-45	1044.67
1945-46	583.06
1946-47	1250.27
1947-48	404.55
1948-49	1375.61
1949-50	233.83

Bionomics

Age and Size at Maturity

According to Devanesan and John (1941) the commercial catches are composed of sardines ranging from 6 to 12 cm. with the 10 to 11 cm. groups dominating in the catches. They have not collected young specimens less than 6 cm. from the commercial catches. They found that sexual maturity is attained when the fish reach a length of about 9 cm. Chidambaram and Venkata-

raman (1946) found the commercial catches composed of 6 to 10 cm. sized white sardines and the size at first maturity is 8 cm. Nair (1951 a) found that sex differentiation in the white sardine takes place when they are small and the females become recognizable when they measure 7.5 cm. while the males could be distinguished only when they measure 8 cm. He found that the mature white sardines and spawning individuals are generally encountered within a narrow size range of 10 to 10.9 cm. in length.

Fecundity

The complete atrophy of the right gonads is a characteristic feature of the white sardine. The left testis and ovary alone are functional and this is partly responsible for the low fecundity of about 8000 eggs estimated in a mature female (Devanesan & John, 1941 and Nair, 1951 a).

Spawning Season

According to Devanesan and John (1941) the spawning season roughly ranges between the months November and February. Nair (1951 a) noticed that the eggs of white sardine first appear in the coastal waters of West Hill by October and continue till February with the November-January period being the best when the eggs occur in enormous numbers constituting the bulk of the fish eggs in the plankton. His studies on the gonadial condition of the white sardine also showed that the ovaries of most of the females become well developed with mature and sometimes even translucent eggs by the month of October. Spawning females with almost all the eggs in the transparent condition and provided with oil-globules in the clear segmented yolk have been collected from November onwards. By February the bulk of the adult females were spent and recovering. From the evidence provided by the abundant occurrence of the eggs in the plankton and by the changes in the gonadial condition at maturity it is clear that intensive spawning takes place from November to January.

Spawning usually takes place at midnight or in the early hours of the morning. In view of the short life-span of the white sardine Nair (1951 a) expressed the view that the fish passes through the spawning season only once in its lifetime and also the possibility that it may spawn more than once during the spawning season. Mookerjee and Bhattacharya (1950) could not get any direct evidence about the breeding season of the white sardine in the east coast; however, they presumed that the breeding season extends from December to May in the east coast.

Breeding Grounds

Nair (1951 a) observed the maximum occurrence of the eggs of white sardine, sometimes in swarms, in the six to eight fathom foreshore waters. The scarcity of the white sardine eggs in the offshore waters indicates that the fish is a coastal breeder with the relatively shallow inshore waters as its spawning grounds.

Early Life-history

Egg—Delsman (1926 b) collected two types of clupeoid eggs from near Batavia and described a few stages in their development. He identified the smaller of the two with a diameter varying from 0.7 to 0.82 mm. and with three to twenty small oil-globules as that of *Dorosoma chacunda* and the larger with a diameter of about 1mm. and with six to twelve similar oil -globules as that of *Dorosoma nasus*. In 1933 he pointed out that these identifications are not correct since he found the small eggs to be very common north of Surabaya, where *Clupeoides lile* was a common fish in the commercial catches. He, therefore, indicated that the smaller type might belong to *Clupeoides lile* and ascribed the larger one to *Dorosoma chacunda*. Devanesan and John (1941) artificially fertilized the eggs of the white sardine, but the authors failed to trace their development. Nair (1951a) traced the early life-history of the white sardine in detail.

The eggs of the white sardine are pelagic, transparent and perfectly spherical with a diameter varying from 0.7 to 0.8 mm. (Fig. 19). The yolk mass is transparent and spherical and shows clearly the segmented nature charact-

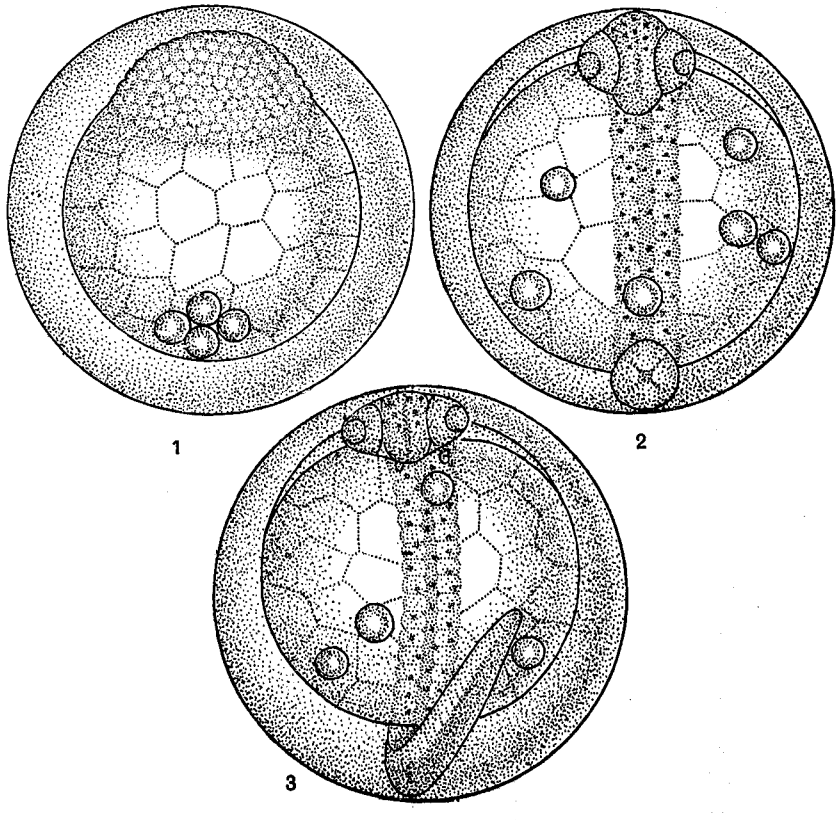


Fig. 19 — Three stages in the embryonic development of *Kowala coval*.
1, Egg at 4 a.m.; 2, Egg at 10 a.m.; 3, Egg prior to hatching at 2 p.m. (x c. 72)

eristic of the clupeoid eggs. A fairly wide perivitelline space is present. Six to eight transparent spherical oil-globules are present in the yolk mass. Extreme variations in the number of oil-globules from 3 to 27 have also been observed in exceptional cases.

Nair (1951a) found that the eggs collected at 4 a.m. show the blastodermal cap fully formed as a dome-shaped structure. The oil-globules occupy the vegetative pole where they are crowded in the peripheral region. With the advancement of development the oil-globules get scattered in the yolk mass. Development is rapid and by 10 a.m. the embryo is well formed and occupies a little more than half the circumference of the yolk mass. The eyes, otocysts and the heart are clearly seen. The myotomes have also differentiated and about 18 of them are present in the embryo in this stage of development. Unlike the other clupeoid eggs, pigment is laid in the white sardine egg even in the early embryonic stage in a characteristic manner. Black unbranched chromatophores are found scattered uniformly on the dorsal side of the developing embryo. Embryonic development is usually completed by 2 p.m. when the eggs are ready for hatching. At this stage the embryo occupies about three-fourths the circumference of the yolk mass and performs frequent twitching movements inside the egg membrane with the aid of the caudal portion which is free from the yolk mass. The full complement of myotomes is formed in this stage.

Hatching—Hatching of the eggs is accomplished very rapidly and takes only a very short time. The first sign of hatching is the slight but quick, elongation of the spherical yolk mass along the embryonic axis to assume a cylindrical shape. The two rounded ends of the elongated yolk mass press against the egg membrane which becomes stretched, losing its spherical shape. The egg membrane splits open at the region of the head owing to the pressure exerted by the elongated yolk mass. The opening thus formed is large enough for the head to be thrust out, but the aperture enlarges by the side to side twitching movements of the larva. The larva slips out quickly through this widened opening up to the caudal portion and by a few lashing movements of the tail rids itself of the shrivelled egg membrane. The process of hatching is completed under laboratory conditions in a short time extending from one to two minutes and it is likely that the duration will be less under the natural conditions in the sea where the process of hatching is accelerated by the movement of water.

Newly Hatched Larva—The newly hatched larva is very inactive and floats on the surface of the water upside down owing to the buoyancy of the yolk and oil-globules. It measures 1.5 mm. in length (Fig. 20). The ellipsoidal yolk mass occupies about half the length of the larva. The free caudal portion of the newly hatched larva is curved but becomes straight gradually in about an hour's time. The myotomes are distinct and about 42 of them are seen in the newly hatched larva. The alimentary canal is long and straight and the vent which is situated far behind the yolk mass opens to the exterior below the 34th or the 35th myotome. The finfold is continuous and entire

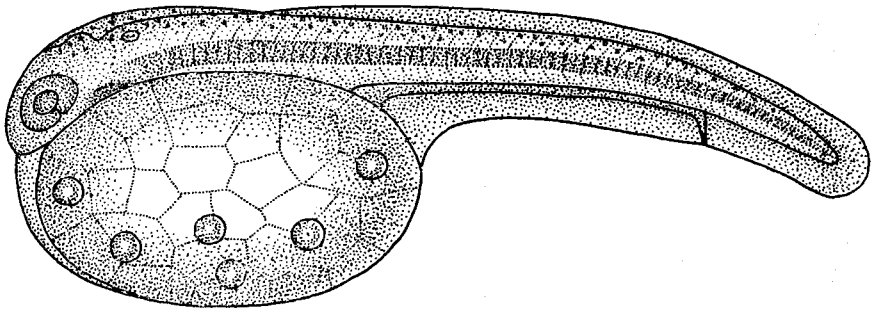


Fig. 20 — Newly hatched larva of *Kowala coval* (x c. 76)

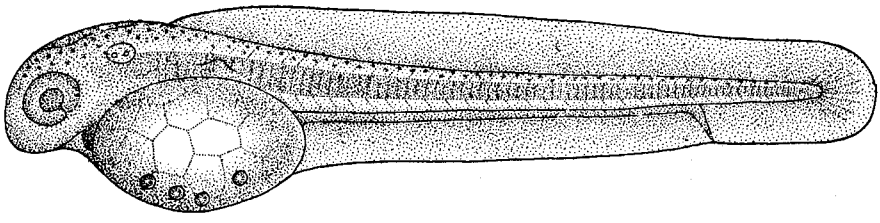


Fig. 21 — One-day-old larva of *Kowala coval* (x c. 51)

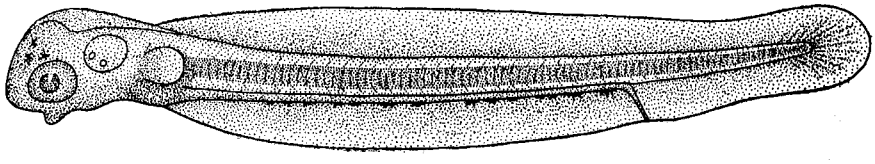


Fig. 22 — Two-day-old larva of *Kowala coval* (x c. 37)

and originates dorsally from the anterior third of the larva. No change in the pigmentation from that of the embryo is seen except an increase in the number of black chromatophores which are uniformly scattered over the entire dorsal side of the larva.

One-day-old Larva—The one-day-old larva (Fig. 21) is very active and the slightest disturbance makes it dart from place to place. The usual elongation of the larva has taken place and it measures 2.25 mm. in length. The yolk mass is reduced in size considerably and the segmentation still seen distinctly. The oil-globules have disappeared completely in some larvae while in others they have become very small. The auditory capsule has increased slightly in size. The pectoral fin has begun to develop and is seen in this stage as a small bud-like prominence above the yolk mass. The finfold has become wider and a slight anterior shifting of its origin has taken place. Indications of the formation of the caudal fin rays are seen in this stage.

Two-day-old Larva—The two-day-old larva (Fig. 22) is very active and usually swims at the bottom of the aquarium. It has grown bigger in size and measures 3.1 mm. in length. The yolk mass has disappeared in most of the

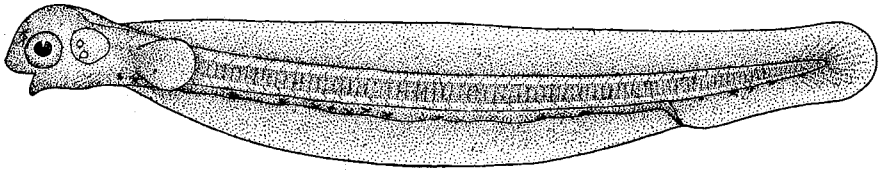


Fig. 23 — Three-day-old larva of *Kowala coval* (x c. 32)

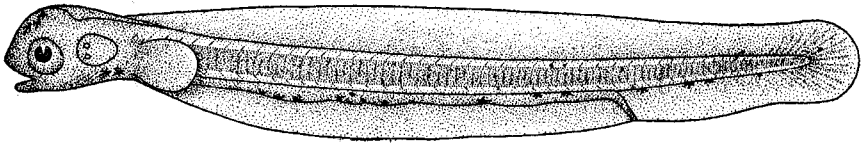


Fig. 24 — Four-day-old larva of *Kowala coval* (x c. 30)

larvae and its remnants alone are seen in some. The mouth has formed and this synchronizes with the absorption of the yolk mass. The pectoral fins have grown into transparent circular flap-like structures. The caudal fin rays are clearly seen in this stage.

Three-day-old Larva—The three-day-old larva (Fig. 23) is a good swimmer and is found to frequent the bottom of the aquarium pecking at the sediments. This larva has increased in length and measures 3.5 mm. The pectoral fins have become larger in size. The caudal fin rays have increased in number and are seen more prominently. A few more black branching chromatophores have appeared in the vicinity of the heart and also along the base of the post-anal finfold. The eyes have become silvery white in colour.

Four-day-old Larva—The larva on the fourth day (Fig. 24) shows no important changes except a slight increase in length to 3.75 mm. Most of the larvae in this stage have become inactive and emaciated in appearance evidently due to lack of proper food. In this condition they become easily susceptible to attacks by ciliates which cause heavy mortality. Many attempts were made to rear the larvae by providing them with fresh planktonic food, but these proved futile and in all cases the larvae died during this critical stage in their life-history.

Adult

Growth and Longevity—Mookerjee and Bhattacharya (1950) studied the growth of the young white sardines found in the Canning river, W.Bengal and stated that the sardines with an average mean length of 2.5 cm. in April reached an average mean length of 7.2 cm. in October. Nair (1951a) studied the length frequencies of the white sardine in the commercial catches at West Hill for three consecutive years and found that the striking feature of the commercial fishery is the presence of only one mode represented by the 10.5 cm. size group which incidentally formed a third of the samples analysed for this purpose during the course of investigation. The unimodal nature of the size frequencies shows that there is only one age group represented in the

fishery. He stated that this size class which dominates the fishery every successive year is the stock recruited during the previous spawning season. Nair (1951a) inferred that the average life-span of the white sardine is about an year with only a relatively small number surviving for a longer period. The new stock recruited during the intensive spawning period extending from November to January apparently grows to a size of about 10 to 11 cm. and dominates the best part of the white sardine season from September to November every year.

Food and Feeding Habits—According to Devanesan and John (1941) *Kowala coval* (Cuv.) is a plankton feeder and the following organisms have been detected by them in the stomach contents:

Zooplankton : Copepods consisting chiefly of *Paracalanus* sp., *Acartia* sp., *Oithona* sp., *Evadne* sp., crab zoea, larvae of bivalves and fish eggs.

Phytoplankton : Species of *Coscinodiscus* such as *C. jonesianus*, *C. gigas* var. *dioramma* and *C. oculusiridis*, *Fragilaria* sp., *Chaetoceros lorenzianum*, *Thallassiothrix nitzschioides*, *Ceratium massiliense*, *Peridinium depressum* and *P. ovatum*, *Tintinnus* sp., *Dinophysis homunculus* and *Biddulphia* sp. They also found that the white sardine is destructive to fish eggs and in one instance its food was found to be composed mainly of the eggs of mackerel. They believed that the white sardine follows spawning shoals of fishes and feeds on their eggs thereby causing natural fluctuations in the abundance of fishes on whose eggs it feeds. Chidambaram and Venkataraman (1946) have recorded *Coscinodiscus*, *Fragilaria*, *Planktoniella*, *Rhizosolenia*, cirripede, copepods, *Euterpina*, *Evadne*, fish eggs, larval bivalves, *Lucifer* and prawns as the food of the white sardine.

Mookerjee and Bhattacharya (1950) found that the diet of the white sardine consists of some algae and benthoic crustacea. Among the algae *Oscillatoria* sp., *Ulothrix* sp., *Hydrodictyon* sp., *Lyngbya* sp., *Cyclotella* sp., and some spores are found in the stomach contents. *Daphnia* sp., *Cyclops* sp., *Calanus* sp., *Eubranchiata* sp., *Mysis* sp., various kinds of decapods like small shrimps and crabs and various crustacean stages like Zoea, Megalopa, Cypris and Nauplius are the chief items of crustacean diet. They found that the percentage of algal diet is not more than 3 per cent. They also found that most of the algae remain undigested as revealed by the examination of the post-intestinal contents and concluded that the fish is carnivorous and chiefly lives on crustacea. Bapat and Bal (1950) found that the food of the young forms of *K. coval* consists mainly of copepods and other crustaceans. A small percentage of diatoms was also noted by them.

Nair (1951a) made a detailed qualitative and quantitative study of the food components and found that the most favourite food is *Evadne* which has been noticed to constitute the bulk of the food of the fish whenever the cladoceran occurs in swarms in the foreshore waters. This tendency to feed on *Evadne* is more pronounced in the juveniles. Penaeid larvae, larvae of other crustaceans, *Lucifer* and the common copepods of the genera *Acartia*, *Corycaeus*, *Temora*, *Oithona* and *Euterpina* are the other important zooplanktonic forms

contributing to their food. Occasionally fish eggs mostly those of *Caranx* have been observed in the stomach contents in fair numbers but no fish larvae have been encountered in the stomach contents. Of the phytoplanktonic elements large numbers of *Thallassiothrix frauenfeldii* and *T. longissima* occasionally constitute the main food, but other genera like *Nitzschia, Fragilaria, Coscinodiscus, Chaetoceros* and *Rhizosolenia* have also been observed to contribute regularly to the food of the white sardine.

It has also been observed by Nair (1951a) that there is intensive feeding during the post-monsoon months when there is rich production of plankton and this active feeding results in the accumulation of large quantities of fat in the abdominal cavity enveloping the viscera. This fat is utilized during the spawning period and no trace of it is seen in the spawners and spent individuals.

Population

Sex Ratio—Nair (1951a) noticed that the females form a slightly higher percentage than the males in most of the size groups in the catches. A reduction in the number of females is observed by him and this was attributed to a higher rate of spawning mortality in the females.

Parasites—An unidentified cymathoan ectoparasite has been frequently noticed under the operculum of the white sardine (Nair, 1951a).

FISHERY

Exploitation

Fishing Areas—The white sardine supports a very important fishery along the west coast and it is confined to a narrow five to seven mile strip of the coastal waters. The most important white sardine centres along the South Kanara and Malabar coasts are: Malpe, Kizhur, Puthiappa, Kadalundi, Parappanangadi, Tanur, Kootayi, Veliangode, Palapetty, Edakazhiyur, Vadanapalli, Nattika, etc.

Fishing Gear—The most common nets used in the white sardine fishery are the gill-net (*Chooda vala*) and the boat-seine (*Paithu vala*). Other types of gill-nets like *Mathichala vala* and boat-seines like *Nethal vala* suited for the capture of oil sardine and whitebait are also used whenever the white sardine shoals are encountered unexpectedly while fishing for these shoaling fishes. The dimensions of the gill-net (*Chooda vala*) and the boat-seine (*Paithu vala*) are given below:

Net	Length	Breadth	Size of mesh	Material
Gill-net (*Chooda vala*)	18 m.	3 m.	1 cm.	Cotton
Boat-seine (*Paithu vala*)	Bag 12-13 m.	...	0.5-1.5 cm.	Cotton
	Platform 18 m.	...	20-23 cm.	Coir
	Wings 49 m.	...	92 cm.	Coir

The method of operation of these nets is similar to that of the gill-nets and boat-seines employed in the oil sardine fishery (Nair & Chidambaram, 1951). The boat-seine *Paithu vala* is usually employed during the peak of the fishery when large shoals frequently enter the coastal waters and immense catches are obtained with this net which, with its wings and platform, is ideally suited for the capture of the pelagic shoaling fishes. On the other hand the gill-net *Chooda vala* used exclusively for the capture of this fish, as the name implies, is used during the rest of the season for the capture of smaller shoals (Nair, 1951a).

Fishing Season—Devanesan and John (1941) and Nair (1951 a) state that the fishery of this sardine commences on the west coast in July and lasts till March. According to Nair very heavy catches constituted mainly by fishes ranging in length from 8 to 11 cm. frequently occur during the September-November period of the fishing season.

Utilization

As Food—The white sardine is mostly consumed by the local people in the fresh condition and when there are heavy catches, the surplus is usually cured with salt in proportions ranging from 8: 1 to 10: 1 (Nair, 1951 a).

FISHERY OF THE LESSER SARDINES

Fishing Craft and Gear

The lesser sardines are generally caught along with the other shoaling fishes by the several types of gear used in the different regions of both the coasts of India. The crafts used are mainly the non-rigid catamarans and the *Masula* on the east coast and canoes and large rigid boats on the west coast. Catamaran is the most commonly used fishing craft of the east coast and it is a keel-less raft formed by lashing together a few logs of wood. Several variations in its construction are found in different regions of the coast. The most common craft of the west coast is the dug-out canoe and it is widely used for the operation of all the nets.

There is a great variety of fishing tackle used in the pelagic fisheries with variations in dimensions and mesh size and they could be conveniently classified under bag-nets and boat-seines, shore-seines, drift-nets and gill-nets and cast-nets. Bag-nets and boat-seines known by various names in different regions are conical nets with or without wings. Two catamarans or two canoes operate these nets. Shore-seines are of two types. The first type is small with a bag and two wings and is used in Orissa, Andhra Pradesh and Tamil Nadu while the other type includes the biggest shore-seine, namely the *Rampani*, operated along the coasts of Mysore and Maharashtra States. Gill-nets and drift-nets are of several varieties and the size and mesh of these nets differ appreciably according to the types of fishes available in different regions of the coastline. Stringed and unstringed cast-nets are used exten-

sively along both the coasts either from a craft or from the shore. Hornell (1927, 1941) has given an account of the fishing methods practised along the Coromandel and Malabar coasts.

Exploitation

Sardinella gibbosa (Bleeker)

This sardine rarely occurs as a single species fishery in any of the regions and it is always found in association with either *S. fimbriata* (Cuv. & Val.) or *S. albella* (Cuv. & Val.). In Andhra Pradesh it is recorded from Lawson's Bay and it occurs in the commercial catches along with *S. fimbriata* (Cuv. & Val.). In Tamil Nadu it forms an extremely good fishery and in the south-east coast extending from Devipatnam to Kanyakumari it is caught along with *S. albella* (Cuv. & Val.). This sardine forms only a negligible fishery in Kerala and Mysore States. Table 18 gives the estimated landings of *S. gibbosa* (Bleeker) in different maritime States.

Table 18 — Estimated Annual Landings of *S. gibbosa* in Different States During 1950-68
(in tonnes)

Year	Andhra Pradesh	Tamil Nadu	Kerala	Mysore	Maha-rashtra	W. Bengal & Orissa	Total
1950	...	167	...	...	...	...	167
1951	...	639	...	...	...	...	639
1952	...	12	9	...	...	...	21
1953	...	346	51	5	...	...	402
1954	...	86	...	...	...	...	86
1955	39	169	...	...	...	...	208
1956	...	226	...	15	...	...	241
1957	...	890	37	...	...	...	927
1958	1	743	87	...	...	...	831
1959	289	1,659	4,269	...	4	...	6,221
1960	207	1,405	1,036	...	52	...	2,700
1961	228	646	58	...	...	...	932
1962	46	836	12	...	...	...	894
1963	193	300	1	12	...	...	506
1964	517	1,235	117	15	...	802	2,686
1965	276	164	30	...	...	...	470
1966	...	1,699	1	...	...	...	1,700
1967	...	124	276	...	...	...	400
1968	...	98	403	...	...	...	501
Average	95	602	336	2	3	42	1,081

Along the east coast of Tamil Nadu this sardine occurs throughout the year and two distinct peak periods during March-April and October have been observed in the fishery. In Kerala and Mysore coasts this sardine contributes to an erratic fishery and is caught in small numbers generally during November-December.

Sardinella albella (Cuv. & Val.)

This sardine contributes to a good fishery along the west coast only and is found in the commercial catches along with *S. fimbriata* (Cuv. & Val.). It generally forms only a small percentage of the fish production in Maharashtra, Mysore and Kerala States. Fishing for this sardine is done throughout the year except during the monsoon months of June and July. Two peak periods in the fishery have been noticed on the west coast during February and August-September. On the east coast the fishery is confined to Tamil Nadu and extends from April to July and September to December, the best month being April. The estimated State-wise landings are given in Table 19.

Table 19 — Estimated Annual Landings of *S. albella* in Different States During 1950-68
(in tonnes)

Year	Tamil Nadu	Kerala	Mysore	Maharashtra	Total
1950	...	...	...	639	639
1951	...	...	7	2,377	2,384
1952	...	...	585	...	585
1953	...	18	47	...	65
1954	...	117	71	87	275
1955	...	12	...	...	12
1956	...	101	74	...	175
1957	69	207	88	6	370
1958	217	162	145	...	524
1959	578	3	66	...	647
1960	320	346	63	...	729
1961	214	12	...	...	226
1962	751	109	2	...	862
1963	326	26	1	...	353
1964	148	284	...	24	456
1965	20	85	...	75	180
1966	16	208	14	...	238
1967	170	40	20	...	230
1968	99	...	...	...	99
Average	154	91	62	169	476

Sardinella fimbriata (Cuv. & Val.)

This sardine is found along both the coasts of India and contributes to a good fishery in all the maritime States. Fishing for this sardine is done throughout the year excluding June to August. It is seen from the All-India production of this sardine (Table 20) that the west coast produces on an average one and a half times more than the east coast. The peak period of the fishery along the east coast is during December-January whereas along the west coast two peak periods are known in March-April and November-December. Nair (1951b, 1953b) pointed out that the success or failure of the oil sardine fishery exerts a profound influence on this and other sardine fisheries of the west coast and the former being a highly priced fish its fishery is intensively exploited neglecting to some extent the fisheries of the other sardines.

Table 20 — Total Annual Production of *S. fimbriata* in India During 1950-68

(in tonnes)

Year	East coast	West coast	Total
1950	23,345	23,456	46,801
1951	9,591	28,183	37,774
1952	10,750	13,076	23,826
1953	10,472	7,306	17,778
1954	7,508	2,580	10,088
1955	7,255	18,182	25,437
1956	7,975	10,662	18,637
1957	5,440	21,468	26,908
1958	1,459	18,753	20,212
1959	2,661	22,216	24,877
1960	4,722	10,377	15,099
1961	6,579	2,975	9,554
1962	5,269	1,421	6,690
1963	7,107	3,390	10,497
1964	9,836	6,367	16,203
1965	8,088	3,885	11,973
1966	32,385	6,553	38,938
1967	9,180	5,608	14,788
1968	7,348	7,804	15,152
Average	9,314	11,277	20,592

Table 21 — Estimated Annual Landings of *S. fimbriata* on the West Coast During 1931-32 to 1949-50

Seasons	Landings (in tonnes)
1931-32	842
1932-33	2,457
1933-34	2,357
1934-35	950
1935-36	337
1936-37	1,262
1937-38	1.434
1938-39	1,666
1939-40	1,231
1940-41	1,842
1941-42	6,661
1942-43	1,338
1943-44	3,004
1944-45	379
1945-46	631
1946-47	3,025
1947-48	1,600
1948-49	4,532
1949-50	732
Average	1909

Chacko (1954, 1955) gave the estimated annual landings of the sardine on the west coast from 1931-32 to 1949-50 seasons. Table 21 shows the estimated catches during the different seasons.

Sardinella sirm (Walbaum)

This sardine has a very restricted distribution and is found only in the Coromandel, Gulf of Manaar and south Kerala coasts. It is particularly abundant in the seas around Madras, Pondicherry, Tuticorin and Vizhinjam where it contributes to a good fishery. The estimated landings of this sardine are given in Table 22.

It is apparent that the fishery is good in Tamil Nadu and Kerala only. The fishery extends throughout the year except August in Tamil Nadu and two peak periods are present in March and December. In the south Kerala region the fishery commences in May and terminates in December with the peak period in September.

Table 22 — Estimated Annual Landings of *S. sirm* in Different States During 1950-68
(in tonnes)

Year	Tamil Nadu	Kerala	Maharashtra	Total
1950	601	...	...	601
1951	958	...	...	958
1952	185	...	350	535
1953	499	798	...	1,297
1954	1,175	4,375	...	5,550
1955	556	...	...	556
1956	1,488	10	...	1,498
1957	1,188	30	...	1,218
1958	584	28	...	612
1959	662	219	...	881
1960	467	14	...	481
1961	1,513	82	...	1,595
1962	534	413	...	947
1963	156	164	...	320
1964	314	213	...	527
1965	24	22	...	46
1966	1,115	319	...	1,434
1967	298	491	...	789
1968	332	737	...	1,069
Average	666	417	18	1,101

Sardinella melanura (Cuvier)

This sardine has a restricted distribution in the Indian waters and is found in the south Orissa and south Kerala coasts only. This sardine is caught along with *S. fimbriata* (Cuv. & Val.) (Nayar, 1958). The estimated annual landings in these two regions are given in Table 23.

Sardinella sindensis (Day)

This sardine occurs in isolated places only and in recent years it has been caught in small quantities in the commercial catches at Kanyakumari, in 1956 (117 tonnes) and at Cuddalore and Porto Novo in 1958 (8 tonnes) only.

Sardinella clupeoides (Bleeker)

This sardine occurs in the commercial catches in the Gulf of Manaar and is of some importance in south Kerala where it occurs along with *S. sirm* (Walbaum) and *S. melanura* (Cuv.) and no separate catch data are available.

Table 23 — Estimated Annual Landings of *S. melanura* During 1950-68
(in tonnes)

Year	Orissa	Kerala	Total
1950	5,462	1,554	7,016
1951	1,466	882	2,348
1952	309	9,837	10,146
1953	48	...	48
1954	194	195	389
1955	...	...	...
1956	...	...	...
1957	...	...	...
1958	...	...	...
1959	...	2	2
1960	...	...	...
1961	...	...	...
1962	...	...	...
1963	...	...	...
1964	...	...	...
1965	...	1	1
1966	...	...	...
1967	...	...	...
1968	...	...	...
Average	394	656	1,050

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