NOTES ON THE EGGS, LARVAE AND JUVENILES OF THE INDIAN SPRAT, *SARDINELLA JUSSIEU* (LACEPÈDE)

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Sardinella jussieu = *Sardinella gibbosa* (Bleeker), popularly known as the Indian sprat, is one of the commercially important sardines occurring in Indian coastal waters. No adequate information is available hitherto on the early development of this fish although work was in progress on some aspects of its fishery and biology (Devanesan, 1932; Chacko, 1946, 1950; Sekharan, 1955, 1959; Ganapati and Rao, 1957; Dharmamba, 1959; Bennet, 1961; Dutt, 1961). While examining the plankton collected off Cannanore, south-west coast of India (surface hauls from the 6-fathom station sampled by a ¾ metre net of fine organdie cloth), during January-May 1964, a search for the eggs and larvae of *S. jussieu* was made because partly and fully spawned specimens appeared in large numbers in the local catches of both indigenous crafts and mechanised vessels. The effort was successful since eggs and larvae identified as of this species were isolated in the course of this period. During the months of May and June 1964 juveniles began appearing in the shore-seine and boat-seine catches. The present paper gives the salient features of the eggs, larvae and juveniles available in the collections. All the figures and measurements of the larvae given are made on the material preserved in formalin. The larvae in formalin are transparent with a tinge of whitish colouration in the younger stages, but the older stages are opaque and whitish. The terms 'pro-larva', 'post-larva', etc., are used in accordance with the definitions given by Jones (1950).

PLANKTONIC EGGS

The planktonic eggs of *S. jussieu* are pelagic, transparent and spherical having a diameter range of 0·589–0·749 mm in the living condition and of 0·550–0·680 mm in formalin. The yolk is centrally placed, highly vacuolated, measuring 0·577–0·599 mm in diameter in the living condition and

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0·403–0·508 mm diameter in formalin. It contains one oil globule of glistening golden-yellow colour measuring 0·120 mm in diameter. The perivitelline space in the earliest stage of development present in the collections is narrow and becomes wide in advancing stages of development, a phenomenon observed in the case of sardine eggs.

Three representative stages in the embryonic development of *S. jussieu* are available in the collections. In the earliest condition (Fig. 1) cleavage has been completed and the germinal disc is in the process of spreading over the yolk, almost half of which is covered by it. In the next stage (Fig. 2) the embryo is indicated. It is unpigmented and has a broad, somewhat oval-shaped head region followed by a narrower trunk region, the anterior part of which alone is visible. The optic cups and their lens are also seen in this stage. In the oldest condition of the embryo available (Fig. 3) the trunk and the tail are formed but the alimentary canal is not yet visible. Rudiments of the larval fin-fold are seen on the dorsal and ventral aspects of the tail which is free from the yolk. The embryo is pigmented with black chromatophores scattered on its dorsal side, dense in the head region and sparse in the rest. This pattern of pigmentation is characteristic of the advanced embryonic stages of sardines.

Larval Stages

The salient features of ten representative stages in the larval history of *S. jussieu* available in the collections, from an early pro-larval condition to an advanced post-larval stage in which almost all the larval features have disappeared, are summarised below:

I. 1·28 *mm larva* (Fig. 4)

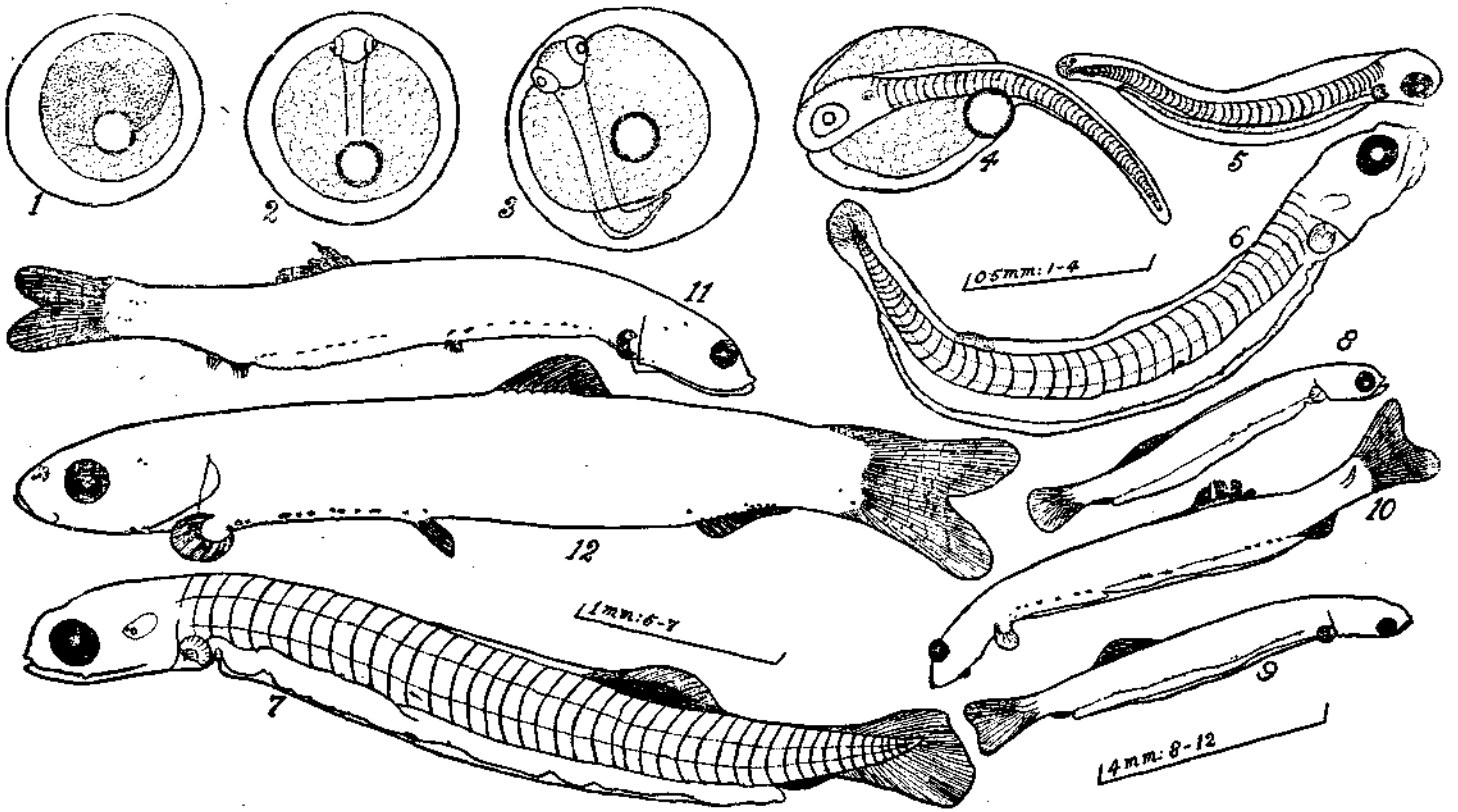
This is an early pro-larval stage characterised by the presence of a large and prominent yolk-sac, lack of pigmentation of the eyes and absence of the mouth. The yolk-sac is somewhat oval in shape and is rounded off posteriorly, a feature diagnostic of the early pro-larvae of sardines. The oil globule occupies the hind end of the yolk-sac and is of the same colour and size as the oil globules of the eggs. The head is not free from the yolk, somewhat club-shaped, tapers gradually in the hinder region as the trunk which ends in an almost pointed tail-tip. The fin-fold is entire and continuous. It commences from the post-orbital region dorsally and ends at the hind end of the yolk-sac ventrally. The larva measures its maximum height in the middle of the yolk-sac. The vacuolated yolk is followed by a tubular alimentary canal that ends in the anus situated below the 39th myotome. The

precise number of the post-anal myotomes is difficult to be ascertained as they become indistinguishable near the tip of the tail. However, excluding the tail-tip the boundaries of about 7 myotomes are visible in this region. The total number of myotomes, about 46, is higher than the vertebral number of the adult namely 45. It may be noted in this connection that in clupeiform larvae the number of myotomes in the pro-larval condition is a little higher than the adult vertebral count and gets stabilised with it only as development progresses. The larva is pigmented with black chromatophores scattered along its dorsal side, densely distributed in the head region and sparsely in the region behind it. The dorsal pigmentation is another distinguishing character of sardine pro-larvae.

From the very early developmental features of this stage such as the presence of a prominent yolk-sac with no traces of yolk in the alimentary canal, the intact oil globule, the attachment of the head to the yolk-sac as well as the similarity in the pigmentation of the larva to the oldest embryonic stage observed, it is obvious that the pro-larva in this condition represents a stage not much older than the newly-hatched larva.

II. 2·20 *mm larva* (Fig. 5)

In this stage the mouth is formed, yolk has disappeared and the eyes are pigmented, pointing out that the larva has entered the post-larval phase of its development. The body is elongated and tapers posteriorly. The head has become somewhat globular. The mouth is rather inferior in position. The jaws are not yet visible. The fin-fold has become broader than in the previous stage. The number of preanal myotomes has decreased to 36, obviously by the forward movement of the anus, a phenomenon observed in clupeiform larvae. The myotomes in the postanal region have developed quite discernible boundaries and are 9 in number. The total number of myotomes in this stage of the larva, 45, has thus become stabilised and corresponds with the total number of vertebrae in the adult. However, the disposition of the myotomes is different from the disposition of vertebrae in the adult (29 pre-anal and 16 post-anal) and becomes similar to the latter only in the advanced post-larval phase. Laterally behind the region of the head a somewhat circular membraneous flap-like structure, representing the pectoral fin has developed. Striations indicating the future rays are present in the caudal region of the fin-fold as well as in the pectoral flap. Black chromatophores are present along the ventral aspect of the alimentary tract in this stage. From the migration of pigments in sardine larvae observed by many an author, it appears that these chromatophores are the



FIGS. 1–12. Stages in the embryonic and larval development of *S. jussieu*. Figs. 1–3. Eggs three stages: before the formation of the embryo, embryo in eye developing phase and embryo with tail developing phase; Figs. 4–12 Larvae in nine stages: Fig. 4. Early prolarva; Fig 5. Early postlarva; Fig. 6. Postlarva having the dorsal fin in an early stage of development; Fig. 7. Postlarva having the anal fin in an early stage; Fig. 8. Postlarva having almost round caudal fin; Fig. 9. Postlarva with lower jaw longer than the upper; Fig. 10. Postlarva with forked caudal fin; Fig. 11. Postlarva with pelvic fin in an early development stage. Fig. 12. Postlarva with some juvenile features and a few larval characters.

ones migrated from the dorsal side of the larva present in the previous stage. A few black chromatophores are also present below the tail.

Although the post-larva in this stage is in a far advanced condition of development from the previous pro-larval stage, the absence of any indications of the dorsal, anal as well as pelvic fins and the presence of a prominent fin-fold point out that it is only a stage in the early post-larval phase of development.

III. 4·26 *mm larva* (Fig. 6)

The important change noted in this stage over the previous is the indication of the dorsal fin in the last third of the larva, a little in front of the level of the anal region. The body has become elongated and widened; but corresponding with this the fin-fold has not become larger. The caudal and the pectoral fins have become more prominent. A small depression has developed above the optic region. The head has lost the globular shape and has become somewhat elongated. The pre-optic region (snout) has become longer than in the previous stage. The upper and the lower jaws have become prominent and somewhat pointed in the tip. The anus has further moved forward and opens below the 33rd myotome. The post-anal myotome number has increased to 12. The pigmentation consists of streaks of chromatophores along the ventrolateral aspect of the gut and a small group above the midgut.

IV. 5·36 *mm larva* (Fig. 7)

This stage is characterised by the appearance of the anal fin behind the region of the vent. The larval fin-fold is considerably reduced and appears as a narrow membrane along the dorsal and ventral aspects of the body. The caudal fin has become somewhat rhomboidal and the dorsal fin has assumed a rather triangular shape. A few chromatophores have appeared along the dorsal aspects of the fore- and hind-guts. The number and disposition of the myotomes in this stage as well as the succeeding two remain the same as in the previous.

The larvae in the following three stages of development, *V*, *VI* and *VII*, measuring 6·72 (Fig. 8), 7·77 (Fig. 9) and 9·92 mm (Fig. 10) respectively, do not appear to have undergone significant changes in development. The fin-fold is present in all the three stages but in a highly reduced form. In the 6·72 mm. larva the lower jaw has become longer than the upper and

the hind margin of the caudal fin has become somewhat rounded. The beginning of bifurcation of the caudal fin is noticed in the 7·77 mm stage which has minute golden-yellow spots in the anterior mid-lateral aspect and at the base of all the myotomes in the living condition. The anus in the 9·92 mm larva opens below the 30th myotome, its forward movement covering 3 myotomes observed over the previous stage. The number of post anal myotomes has increased to 15. The snout has become longer and equals eye diameter in this stage. The fin-rays in all the fins are under progressive growth; but their precise number is difficult to be ascertained owing to the absence of clear-cut demarkating boundaries. About 13 dorsal, 12 anal and 30 caudal rays appear more prominent than the rest. A few chromatophores have appeared at the base of the lower caudal lobe in this stage.

VIII. 13·45 *mm larva* (Fig. 11)

The notable feature in this stage is the development of the pelvic fin in the form of a few rays. The origin of the pelvic is well in front of the level of the anterior aspect of the dorsal fin. The pre-pelvic length of the larva is shorter than the post-pelvic length. The remnants of the larval fin-fold present until the 9·92 mm stage has disappeared in the present one. The body has become somewhat vermiform and the lateral sides are more convex than the contour observed in the previous stage. Minute conical teeth are present in the upper jaw. Dorsal fin has about 15 prominent rays while their approximate number in the anal and caudal fins remain the same as in the previous stage. The predorsal length of the larva has become smaller when compared with its proportion observed in the previous stage. This is obviously by the forward movement of the dorsal fin, a phenomenon observed in sardine larvae. The number and disposition of the myotomes in this stage as well as the succeeding one remain the same as in the previous.

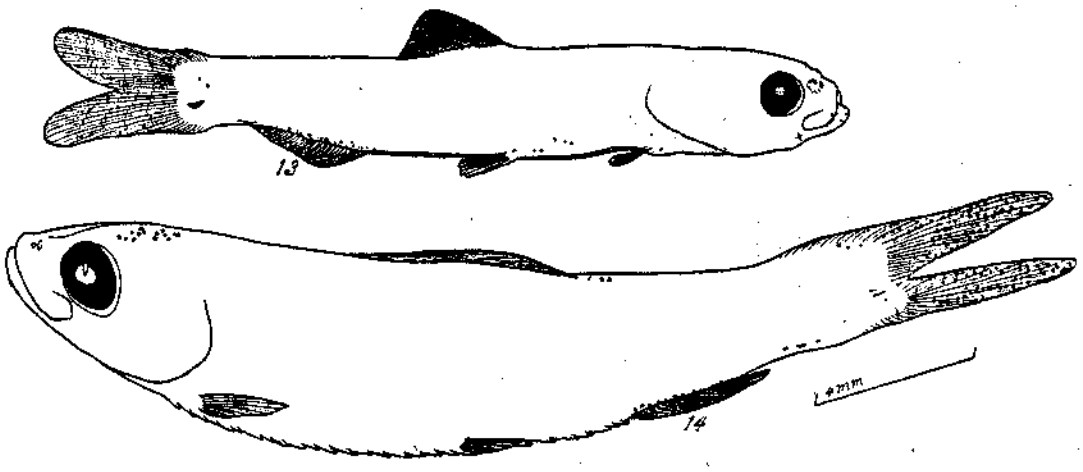
IX. 17·30 *mm larva* (Fig. 12)

The larva of this stage shows the beginnings of the appearance of the juvenile features as well as the gradual disappearance of the still existing larval characters. The body has become wider and the head more massive. The narial openings have developed in the snout and the mouth has become almost terminal. The distance between the levels of the origin of the pelvic and of the anterior aspect of the dorsal has become shorter. The pre-dorsal length has become shorter than the condition in the previous stage. The pectoral rays have become more thickened. The pelvic fin has aquired a

somewhat triangular shape. The precise number of rays in the fins still remains difficult to be ascertained. Along the base of the anal fin a few chromatophores have appeared.

X. 22·24 *mm larva* (Fig. 13)

This is an advanced stage in which almost all the larval features have disappeared. Though this stage shows many a juvenile character, the absence of the ventral scutes and the difference in the disposition of the dorsal and pelvic fin from the juveniles, do not permit its classification as a juvenile. The body has become wider and more massive and the larva more sardine-like than the condition observed in the previous stage. The pre dorsal and post-dorsal lengths have become almost equal. The origin of the pelvic in this stage is below the level of the anterior aspect of the dorsal fin. The head in relation to the total length of the larva has become longer when compared with their proportions in a few of the preceding stages. In the 9·92 and 13·45 mm stages the head is about 1/6th of the total length; in the 17·30 mm larva it is about 1/5 while in the present stage it has become 1/4 of the total length. It appears from these as though the head in the post-larval phase of development undergoes a more rapid growth than the rest of the body, reaching the maximum in the present stage. The number of rays in the fins is quite discernible, about 15 dorsal, 13 pectoral, 7 pelvic, 18 anal and 34 caudal. Pigmentation of the caudal fin has increased. A few stellate chromatophores have also appeared on the jaws. In the living condition golden-yellow spots referred to in 7·77 mm stage were present.



FIGS. 13–14. An advanced postlarva and a juvenile stage of *S. jussieu*. Fig. 13. Postlarva in which almost all the larval characters are lost; Fig. 14. A juvenile, 26·7 mm total length,

The anus in this stage has further moved forward and opens below the 29th myotome; the post-anal number has increased to 16. The disposition of the myotomes in this stage is identical with the disposition of the vertebrae in the adult.

JUVENILES

Two juveniles in an early stage of development, measuring 24·7 and 26·7 mm (Fig. 14), whitish in colour were collected on 18–5–1964 from the shore-seine units at Cannanore by Mr. K. V. Narayana Rao, to whom I am indebted for placing them at my disposal. Besides, a few juveniles in a longer size-range, 33–48 mm, having light greenish colouration dorsally and whitish ventrally were collected from the shore-seine and boat-seine catches at Cannanore during May and June 1964. The morphometric data of both the groups are presented in Table I. The pre-dorsal length has become

TABLE I

Measurements of the juveniles of S. jussieu *in mm collected from the shoreseine and boat-seine catches at Cannanore*

Serial No.	Date of of collection	Total length	Standard length	Length of head	Length of snout	Eye dia-meter	Depth of body
1	18–5–1964	24·7	19·4	5	1·5	1·5	5
2	18–5–1964	26·7	21·4	5	1·5	1·5	5
3	20–5–1964	33	27·5	6·5	1·75	2·5	7
4	20–5–1964	37	31	7	2	2·5	7·5
5	20–5–1964	40	32	8	2	2·75	8
6	2–6–1964	48	39	9·5	2·5	3·25	9·5

smaller than the post-dorsal length showing that the dorsal fin has moved still further over the condition in the oldest post-larva. The pelvic fin is situated below the level of the middle of the dorsal. The head length of the juveniles in relation to their total length is 1/5 on the average, thus showing that the head has become proportionately smaller than the oldest post-larval condition. It appears as though once the larval characters are

lost the head does not grow so rapidly and after a particular stage the head probably grows in a uniform manner as the rest of the body. Thus the morphometric data of post-larvae and juveniles suggest that the pattern of linear growth in the post-larval phase is different from the juvenile condition.

The fin-ray counts of 24·7 and 26·7 mm juveniles are D15, P13, V7, A18 and C38, while those of 33–48 mm group are D16–18, P13, V7, A17–19 and C36–38. The number of scutes in the smaller group are 20 pre ventral and 10 post-ventral while the number in the larger group are 18–19 pre ventral and 10–12 post-ventral. The former have a pre-orbital depression dorsally and a faint indication of a crest in the supraorbital region. The supraorbital crest in the larger group is more prominent and ascends posteriorly.

The pigmentation in the smaller juveniles shows some increase from the condition observed in the oldest post-larva. There is a trace of pigmentation in the tip of the snout and two branching chromatophores on the inner side of the tip of the lower jaw. Similar chromatophores have appeared on either side of the dorsomedian line posterior to the eyes. Behind the dorsal fin a few chromatophores are seen while along the base of the anal fin there is a series of pigments sunken below the body wall. Pigmentation of the caudal fin has become denser and more extensive with many branching chromatophores. Pigmentation in the larger juveniles has increased still more. The small cluster of post-orbital chromatophores noticed in the smaller group has become larger and diverge from each other anteriorly with more growth. Two minute black pigment spots have appeared on the anterior aspect of the maxillary bone. The mandibular region shows a few chromatophores anteriorly. While viewing the juveniles on their ventral side the mandibular chromatophores appear in the form of a straight line on each side covering posteriorly. Along the base of the dorsal fin a row of chromatophores has appeared on either side. In between the dorsal and caudal fins a series of chromatophores has appeared on either side of the mid-dorsal line. Behind the anal fin also a few numbers are seen. Pigmentation of the caudal fin has increased considerably with numerous streaks, spots as well as branching chromatophores.

Discussion

Based on an examination of the maturity conditions of *S. jussieu* made at Cannanore during 1964, the peak period of spawning of this fish along the Malabar coast appears to last from January to April. Ganapati and Rao (1957) have stated that the spawning season of this fish off Waltair

(east coast of India) begins in February and extends over a prolonged period Thus the period of spawning of *S. jussieu* along both the coasts seems to be almost similar. Among the other species of *Sardinella* occurring along the Malabar coast, *S. albella* is reported to spawn from March to June (Chacko and Mathew, 1955) but no specimens or this fish were available at Cannanore during this period; and *S. longiceps* from June–July to September–October (Nair, 1959). Another common species, *S. fimbriata*, appeared in small numbers during March–June at Cannanore and were in indeterminate as well as immature stages of gonadial maturity. *S. sirm* and *S. clupeoides*, reported to occur along the south-west coast of India, were absent during this period. The lesser known species, *S. melanura*, *S. dayi* and *S. sindensis*, recorded from the seas around India, had not been met with in the fish landings at Cannanore, not only during the time of the present study but also throughout the period 1961–64. The circumstantial evidence thus points out that the eggs and larvae belong only to *S. jussieu*. This assumption is confirmed by the features of the eggs and larvae which distinguish them from those of the species that have certain characters in common with *S. jussieu* (*vide infra*).

Delsman (1926) assigned certain eggs to *Clupea fimbriata* (= *S. fimbriata*) based on the coincident occurrence of the eggs and spawners; and confirmed it by comparing the number of larval myotomes with the adult vertebral number. The eggs of *S. fimbriata* identified by him have a diameter of 1·4–1·5 mm. Bapat (1955) also assigned similar eggs to this species. Subsequently Delsman (1933) collected a smaller variety of sardine egg with diameter not more than 1·1 mm and identified it as of *C. perforata* = *S. perforata*. The eggs of *S. albella* = *C. brachysoma* have two egg membranes while those of *S. sirm* = *C. leiogaster* are considerably bigger and do not contain oil globule as observed by Delsman (1926) and John (1951). The eggs of *S. longiceps* have an average diameter of 1·4 mm (Nair, 1959).

One of the direct methods in identifying the planktonic eggs of sardines is to compare the size of their ripe ova with the size of the yolk of the eggs, because, although with progressive development the eggs become larger, the size of the yolk remains constant and tallies with the diameter range of the ripe ova. It may be noted in this connection that the ripe ova of sardines are devoid of a protective membrane as well as perivitelline space and are made up only of the yolk. The egg membrane develops only after the ova come into contact with the sea-water, then lifts itself from the yolk giving place to perivitelline space and becomes larger and larger with advancing

development (Miller, 1952). But, irrespective of the size of the egg membrane, the size of the yolk remains just as before and is useful in tallying it with the diameter range of the ripe ova of the species to which the eggs belong. Hence an attempt was made to obtain the ripe ova of *S. jussieu* so as to acquire a first-hand knowledge of their characteristics. Unfortunately, this was not successful because the ripe ova in the specimens examined were all found to have been shed already. The few residual ova present were in advanced stages of putrefaction. However, it may be mentioned in this connection with advantage, that the diameter range of the yolk of the planktonic eggs in the living condition, 0·577–0·599 mm, tallies with the diameter range of the ripe ova of this species given by Chacko (1946) namely 0·56–0·60 mm.

In confirming the identification of the larvae as belonging to *S. jussieu*, the differences in the number and disposition of their myotomes as well as in their sizes from the larvae of the closely allied species proved valuable. The vertebral number of *S. albella* and *S. sirm* is 42–43 only and their larvae have 42–43 myotomes as observed by Delsman (1926). The vertebral number of *S. longiceps* varies from 46 to 48 while that of *S. fimbriata* from 45 to 46 (Delsman, 1926; Nair, 1959). Dutt (1959, 1961) from a study of the vertebrae in *S. fimbriata* and *S. jussieu* occurring off Waltair on the east coast has given the range of vertebrae as 44–46 and 45–47 respectively. An examination of the vertebrae of these species occurring off Cannanore during 1964 has however shown that their number in *S. fimbriata* is 45–46 (as given by Delsman, 1926) and in *S. jussieu* is 45 only. Whatever be the overlapping pattern of the vertebrae reported between *S. longiceps*, *S. fimbriata* and *S. jussieu*, the larvae of the first two species differ from comparable larval stages of the third in certain vital features. The newly hatched larva of *S. longiceps* (Nair, 1959) which is in the same developmental phase as the 1·28 mm stage of *S. jussieu*, differs in having 41 pre-anal myotomes from the 39 pre-anal myotome condition observed in the latter. Similarly, the 2-day old larva of *S. longiceps* (Nair, 1959) compared with the 2·20 mm larva of *S. jussieu* differs from it in having 38 pre-anal myotomes as against 36 in the latter. The newly hatched larva of *S. fimbriata* (Delsman, 1926) has 40 pre-anal myotomes. Besides, the larval stages of *S. fimbriata* identified by Delsman (1926) are longer in size and broader in body depth than comparable stages of *S. jussieu*. Thus it is obvious that although the vertebral counts of *S. jussieu* and *S. fimbriata* overlap, the differences mentioned above are useful in separating the larval stages belonging to them. Similarly, the juveniles of *S. jussieu* resemble those of *S. fimbriata* in many a feature but

can be distinguished from each other by the fact that the depth of the body in relation to the standard length is narrower in *S. jussieu* (3½–4) than in *S. fimbriata* (3–3½). This morphometric distinction is useful in separating the adults of the two species also.

Chacko (1946) stated that the planktonic eggs of *S. gibbosa* = *S. jussieu* measured 0·58–0·64 mm in diameter and subsequently gave (Chacko, 1950) the diameter range as 0·68–0·84 mm. He does not appear to have paid due attention to the crucial features of sardine eggs and larvae while identifying those of *S. gibbosa*, as according to Nair (1959) "the eggs assigned by him to *S. gibbosa* is not a sardine egg since they do not possess the wide perivitelline space which is an important character of the sardine eggs.... the anterior position of the anus below the 29th myotome in the larva also show that the eggs described by Chacko belong to some other fish". Besides, Chacko does not appear to have duly examined the similarity in the diameter of the ripe ova to the yolk of the planktonic eggs which he has assigned to *S. gibbosa*.

Summary

The planktonic eggs in three stages of development, ten larvae from an early pro-larval condition to an advanced post-larval stage when almost all the larval features have disappeared, are described together with notes on the major developmental changes undergone. An account of a few juveniles and the salient features by which the eggs, larvae and juveniles may be distinguished from those of the allied species is also given.

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