LARVAE OF THE INDIAN MACKEREL, *RASTRELLIGER KANAGURTA* (CUVIER) FROM THE WEST COAST OF INDIA

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ABSTRACT

Larvae of the Indian mackerel, *Rastrelliger kanagurta* (Cuvier) have been identified by the author from the plankton of the south west coast of India and the Laccadive Sea collected during the cruises of *R. V. VARUNA*. Prolarval and postlarval stages from the size 1.73 mm to 8.6 mm (T.L.) are described from the graded series present in the collections to highlight the salient features during the larval development. This account also represents the first descriptions with illustrations of the mackerel larvae from the west coast of India.

The distribution of the larvae, their occurrence in day and night vertical tows made with the Indian Ocean Standard Net, the relative abundance of larvae in the continental shelf and oceanic waters, their abundance latitude-wise, the size-wise frequency of occurrence of larvae and the Temperature-Salinity, Temperature-Dissolved Oxygen, Salinity-Dissolved Oxygen relationship to the occurrence of the larvae from 38 out of 92 stations in the month of May 1964 are also discussed.

INTRODUCTION

The Indian mackerel *Rastrelliger kanagurta* (Cuvier) has a wide distribution in the Indo-Pacific and contributes to a major fishery, particularly along the south west coast of India. The landings of mackerel in 1970 exceeded 1.6 lakh tonnes, an all time record for this country. However, the fishery is characterised by unpredictable large scale fluctuations. The absence of information on the spawning grounds and life-history of the species in our waters to enable proper estimations of eggs and larval abundance and recruitment has been a handicap in understanding the vagaries of this fishery, particularly as it is now known that the large scale fluctuations in the mackerel fishery are due to fishery independent factors.

No reliable account on the identification of the eggs of the Indian mackerel exists, though eggs collected from the plankton and reported as belonging to this species have been figured (Delsman, 1926; Boonprakob, 1963, 1965), or reported without descriptions or illustrations (Devanesan and John, 1940; Balakrishnan, 1957). Identification of larvae of the Indian mackerel have been few (Matsui, 1963, 1970; Peter, 1969), some incorrect (Delsman,

1926, 1931; Grobunova, 1965); and others very insufficiently described or totally lacking in details to effect positive identification (Kuthalingam, 1956; Balakrishnan, 1957).

This report embodies the results of examination of plankton collections made during three cruises of the erstwhile Indo-Norwegian Project Research Vessel *VARUNA* (Cruises 52-54 covering stations 2250-2344) carried out during May 1964 along the south west coast of India and the Laccadive Sea, from which larvae of *R. kanagurta* have been identified. The collections were made with the Indian Ocean Standard Net (IOS Net) as vertical tows from five metres above bottom to surface along the continental shelf and from 200 m to surface in oceanic waters. During the cruises 185 plankton tows were taken from 92 stations and mackerel larvae were present in 54 tows taken from 38 stations yielding a total of 362 larvae.

It is pertinent to mention here that upto now only one species of mackerel, namely *R. kanagurta* has been recorded along the west coast of India (For synonyms see Jones and Silas, 1964a), and this species along with *R. faughni* Matsui, along the east coast of India (Gnanamuttu, 1972), and *R. kanagurta* and *R. brachysoma* (Bleeker) from the Andaman Sea (Jones and Silas, 1964b). Though *R. faughni* has also a fairly wide spread distribution in the Indo-Pacific, the absence of records of this species from the south west coast of India and the graded series of larvae in the present collections indicate that the latter belong to *R. kanagurta*.

Descriptions of Larvae

The mackerel larvae in the collections include both prolarvae and larvae according to the terminology recommended by Hubbs (1943). Unlike the larvae of tunas and other scombroid fishes, the larvae of *R. kanagurta* lack preopercular spines. They are also characterised by having about 30 myomeres, ten of which are pre-vent in position. The intestine is short and the larvae have very characteristic pigmentation. In order to facilitate identification, the diagnostic characters of some of the stages from the graded series of larvae in the collections are given here. Camera lucida drawings of some of the larvae are given in Figs. 1 and 2, and the salient morphometric and other details are presented below and in Table 1. Standard terminology has been used in the descriptions.

Larva about 1.73 *mm in total length* (Fig. 1a):

The earliest larva (prolarva) in the collection measures about 1.73 mm. The larva being partly curled up, an accurate total length measurement is not possible. The head, especially the mouth with the more prominent lower jaw, the large eyes, the short intestine and the disposition of the melanophore pigments are characteristic. The yolk sac is still present. The upper jaw and

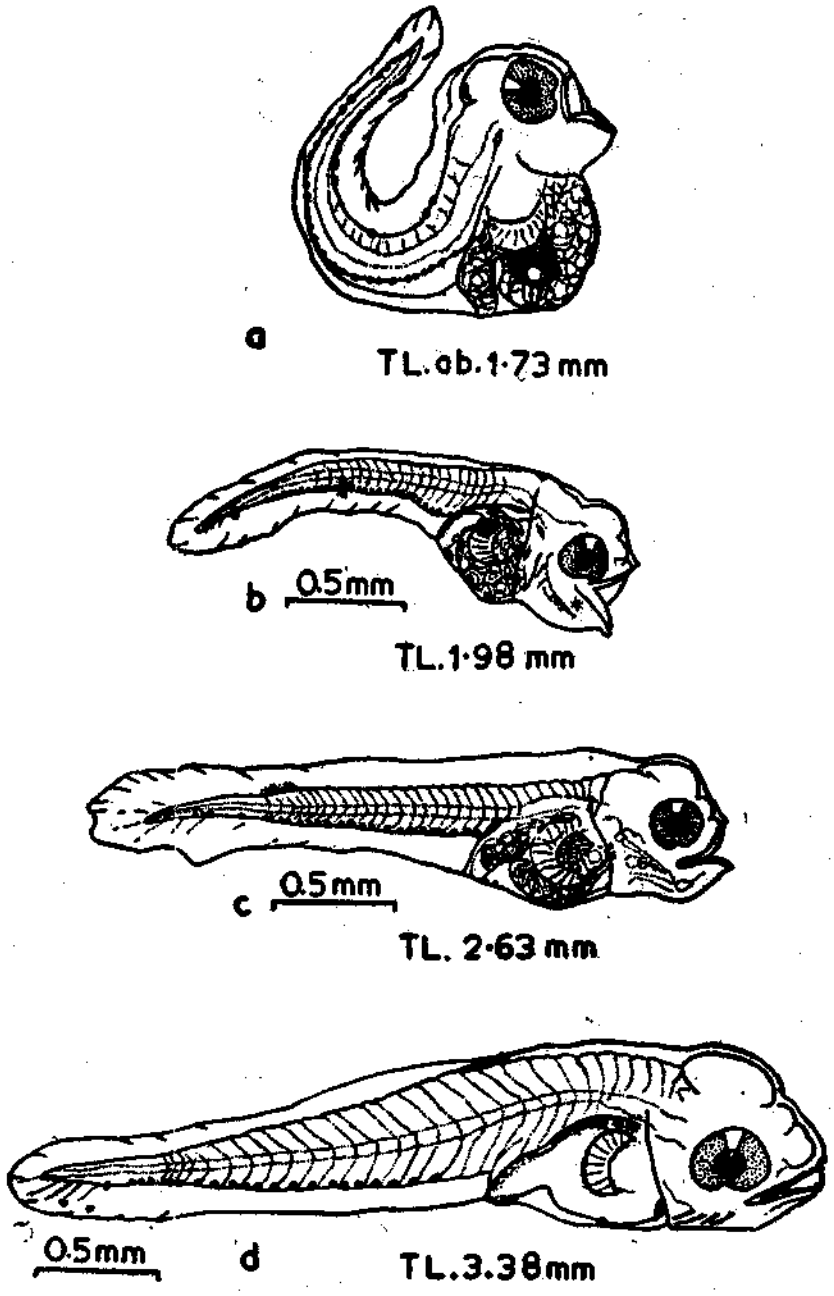

FIG. 1. Camera Lucida drawings of larvae of *Rastrelliger kanagurta* (Cuvier) from the south west coast of India. a. Prolarva about 1.73 mm in TL; b. late prolarva 1.98 mm in TL; c. Larva 2.63 mm in TL; d. Larva 3.38 mm in TL. Head slightly distorted.

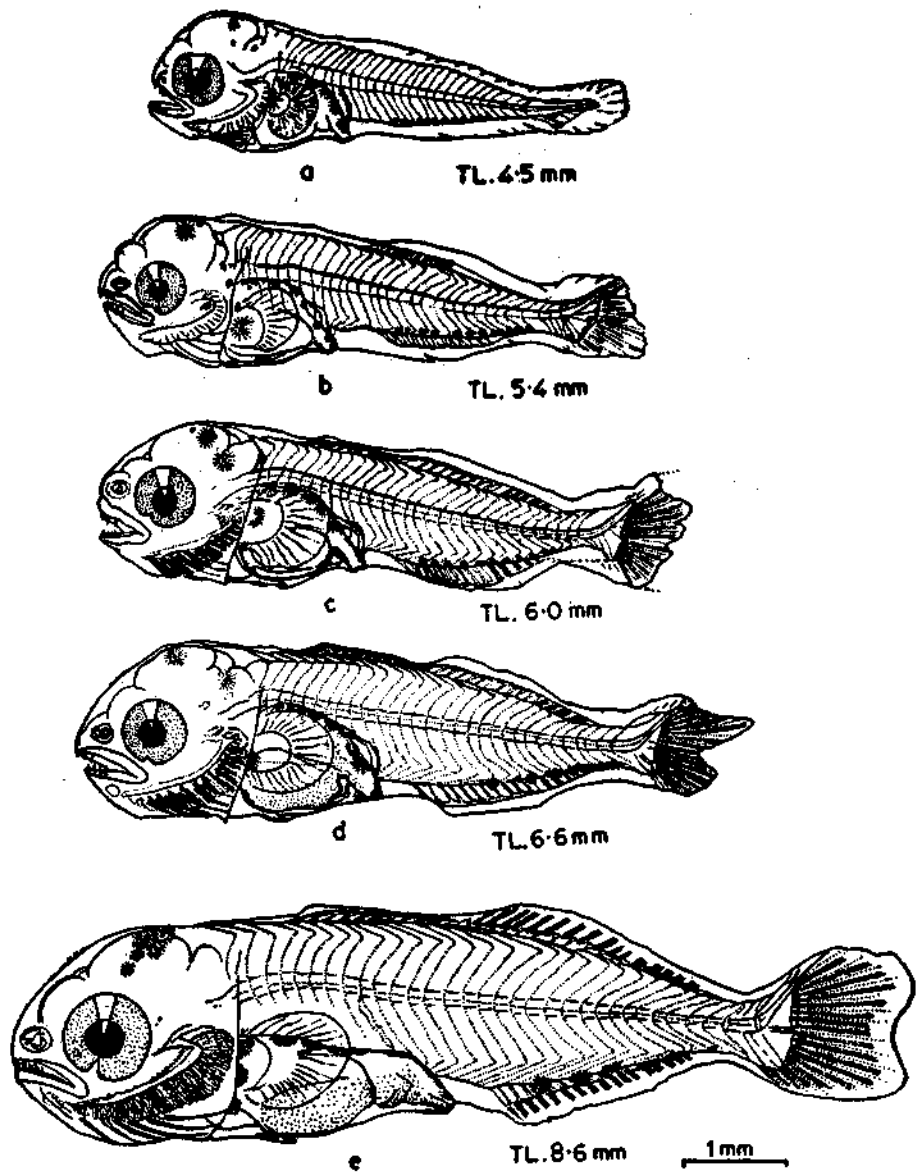

FIG. 2. Camera Lucida drawings of larvae of *Rastrelliger kanagurta* (Cuvier) from the south west coast of India. a. 4.5 mm; b. 5.4 mm; c. 6.0 mm; d. 6.6 mm; and e. 8.6 mm in total length.

snout region appears 'pug-nosed' while the lower jaw is slightly longer. The abdomen has about 10 small melanophores of which atleast five are along the mid-ventral part of the stomach. One melanophore is present above the anterior corner of the vent on the intestine. A row of about 30 melanophores are present dorsal to the visceral cavity from behind the base of the larval pectoral fin to close to the end of the urostyle along the ventral side on the body. At the same time, seven melanophores disjunctly grouped (two in a line vertically above intestine, one above mid-length of body, and three in the posterior third of the body and one slightly ahead of the end of the urostyle) are present along the dorsal side of the body. A black pigment spot is also present on the head. About 13 myosepta are discernible, but not well formed. The jaws are edentulous. Apparently part of the pigment pattern of the embryo before hatching is retained in the prolarva at this stage.

Larva 1.98 *mm in total length* (Fig. 1b):

The development of the pre-vent region is more than the post-vent region. The larval fin-fold is well developed. The proportionate measurements are as follows: Length from tip of snout to end of notochord (denoted in future as body length) 94.94; head 21.71; eye 10.60; maxilla 12.62; snout 4.54; larval pectoral fin 10.60; distance from snout to vent 41.91; snout to first post-vent melanophore 63.13; depth of head at middle of eye 28.28; depth of body at middle of stomach 28.28; depth of body at vent (including dorsal fin-fold) 18.68 per cent of total length. Eye 48.83; snout 20.94 and maxilla 58.13 per cent of head length.

The jaws are edentulous. The myomeres are still not fully differentiated as only 20 myosepta can be counted. The eyes are well developed. The fins are larval. The pigmentation is characteristic with about 28 melanophores present along the lower margin of the body between vent and "urostyle". After the first 14 post-vent melanophores a conspicuous black chromatophore is present. The posterior-most melanophore on the lower side of the "urostyle" is also relatively larger. Anterior to the vent is present one large melanophore and at the middle of the remnant of the yolk sac as well as along the ventral margin of the stomach (abdomen) are present three melanophores. Two pigment spots are also present on the posterior border of the operculum and one mid-dorsally at the occiput. A diffuse pigment spot is also present laterally just below the angle of the lower jaw. The dorsal side of the viscera has a few well developed chromatophores. Branchiostegals are rudimentary.

At this stage, it may be considered still prolarva as the yolk sack is not completely absorbed.

Larva 2.63 *mm in total length* (Fig. 1c):

Body length 95.06; head 20.53; eye 8.74; snout 3.80; maxilla 9.51; larval pectoral fin 9.51; tip of snout to vent 42.96; depth of head at middle of

eye 22.81; depth of body at middle of stomach 20.53; depth at vent 15.21; depth at 20th myosepta 6.84 per cent of total length. Eye 42.6; snout 18.51; maxilla 46.29 and larval pectoral fin 46.29 per cent of head length.

A well developed melanophore is present on the mid-ventral side of the abdomen and another just ahead of the vent in the preanal fold. A dark diffuse chromatophore is present above the stomach and another on the posterior border of the intestine at the place where it bends downwards to the vent. A row of 25 melanophores are present along the ventral side of the body in the post-vent region, the last three and the one ahead of them being separated by wider distances than the rest. The fins are larval. 30 myomeres are present of which 20 are post-vent.

Larva 3.38 *mm in total length* (Fig. 1d):

Body length 96.15; head 21.61; eye 8.17; snout 6.21; maxilla 12.43; distance from tip of snout to vent 40.83; larval pectoral fin 6.28; depth of head at middle of eye 24.55; depth of body at middle of stomach 22.19; depth at vent 17.75 per cent of total length. Eye 42.47; snout 28.76; maxilla 57.53 and larval pectoral fin 28.76 per cent of head length. One tooth present on each side of maxilla and mandible towards anterior border. The more developed head and pre-vent portion of the body give a characteristic dorsal and ventral profile for the larva from this stage onwards. The number of myomeres are 30 of which 20 are post-vent. The myosepta are V-shaped directed anterad. Two conspicuous melanophores are present on the ventral side of the stomach and a third at the anterior corner of the vent. The dorsum of the peritoneal cavity has diffuse chromatophores. 19 melanophores are present along the ventral side of the body behind the vent. In addition, on the lower half of the larval caudal fin two dark melanophores are present. One important difference in the disposition of the melanophores seen at this stage is the absence of melanophores in the first three post-vent myomeres.

Larva 4.55 *mm in total length* (Fig. 2a):

Body length 96.04; head 27.47; eye 11.65; snout 5.49; maxilla 12.09; larval pectoral fin 11.65; snout to vent 47.25; depth of head at middle of eye 27.47; depth of body at middle of stomach 26.37; depth of body at vent 19.78; snout to first post-vent ventral melanophore 54.94 per cent of total length. Eyes 42.40; snout 20.00; maxilla 44.00 and larval pectoral fin 42.40 per cent of head length.

Each side of the upper jaw has three and the lower jaw four minute teeth. The gill arches are with rudimentary gill filaments which are seen through the opercular wall. Branchiostegals are 6. The myosepta of the 10 per-vent and 20 post-vent myomeres are directed anterad. The urostyle shows a very slight upward bend below which the anlages of the hypural plates are seen. Stellate chromatophores are present on the occipital region of the head and

at the base of the larval pectoral fin. Two melanophores are present along the ventral side of the abdomen, while about five chromatophores are present along the dorsal part of the peritoneal wall of the viscera. The post-vent melanophores along the ventral side of the myomeres are absent in the first four myomeres behind the vent, and are present one each on the next 12 myomeres. In addition, one melanophore is present below the middle of the urostyle and one at the tip of the inner most rudimentary hypural plate. The differentiation of the median fins is still not evident. The olfactory bud is developed.

Besides the disposition of the melanophores, two significant changes seen at this length size are: (1) the vent has shifted slightly more posteriorly to be at about 47% of the total length from the snout; and (2) the first four post-vent myomeres and the finfold below it due to the absence of melanophores appears as a conspicuous translucent area posterior to which at a later stage the anlage of the anal fin forms.

Larva 5.4 *mm in total length* (Fig. 2b):

Body length 93.52; head 25.92; snout 6.84; eye 10.19; maxilla 11.67; snout to vent 46.29; larval pectoral fin 11.11; depth of head at middle of eye 25.93; depth of body at middle of stomach 26.85; depth at vent 21.29; depth of body at 20th myomere 14.81 per cent in total length. Eye 39.29; snout 25.00; maxilla 45.00; larval pectoral fin 42.85 and length of maxillary tooth 5.00 per cent of head length.

There is a general change in body form as the urostyle bends upwards and the anlages of the hypural plates are more developed. Early indications of the differentiation of the median fins are seen as the anlages of the second dorsal and anal fin appear and at the same time incipient caudal rays are also seen. Another notable change is the zig zag nature of the myosepta indicating the better development of the musculature. The upper jaw has three teeth and lower jaw four on each side. The disposition of the pigment spots show slight differences (Fig. 2b). A melanophore is also present at the base of the urostyle and two on the distal margin of two of the lower hypural plates. The immediate post-vent translucent area is very conspicuous. On the ventral side of the abdomen there is a distinct melanophore and the primordial of the pelvic fin appears close to this.

Larva 6.0 *mm in total length* (Fig. 2c):

Body length 89.17; head 26.66; eye 10.00; snout 6.66; maxilla 10.83; larval pectoral fin 13.33; snout to vent 46.67; snout to pelvic fin bud 30.83; snout to origin of anal fin 51.67; depth of head at middle of eye 26.66; depth of body at middle of stomach 25.00; depth of body at vent 20.00 per cent of total length. Eye 37.50; snout 25.00; maxilla 40.62 and larval pectoral fin 50.00 per cent of head length.

Anlages of spines and incipient rays of the first dorsal and second dorsal fins (10 + 10), dorsal finlets (5), anal fin (11), anal finlets (5), and caudal fin rays (12 primary) are formed. Pelvic fin bud is clearly seen. The posterior corner of the vent lies midway between tip of snout and tip of urostyle. The disposition of the pigment spots are as shown in Fig. 2c. The two melanophores at the lower base of the caudal fin are more conspicuous. There are only five melanophores at the base of the developing anal fin, four at the bases of the anal finlets and two behind them on the caudal peduncle.

Larva 6.6 *mm in total length* (Fig. 2d):

Body length 89.39; head 25.76; eye 9.85; snout 6.82; maxilla 12.58; larval pectoral fin 11.36; snout to vent 46.21; snout to origin of pelvic fin 30.30; snout to origin of anal fin 53.03; distance from vent to origin of anal fin 6.82; depth of head at middle of eye 25.00; depth of body at middle of stomach 24.24; depth of body at vent 21.21; depth at caudal peduncle 6.06 per cent of total length. Eye 38.24; snout 26.47; maxilla 48.82; larval pectoral fin 44.11; distance from posterior corner of vent to origin of anal fin 26.47 and depth of caudal peduncle 23.53 per cent of head length.

The general body form is as in the 6.00 mm specimen except that the rudiments of the median fins are slightly better developed, with the first dorsal with 10, second dorsal 11, dorsal finlets 5, anal fin 11, anal finlets 5 and caudal fin with 16 incipient primary rays. The position of the vent has shifted slightly posteriorly as the distance from the tip of the snout to the posterior corner of the vent is slightly greater than the distance from the latter to the tip of the hypural. One or two melanophores are present in addition at the base of the caudal fin just below the tip of the hypural, besides the two at the lower caudal base. Only four melanophores are present at the posterior half of the base of the anal fin, while six are present at the anal finlets and the lower side of the caudal peduncle. The pelvic fin bud is more developed.

Larva 8.6 *mm in total length* (Fig. 2e):

Body length 87.28; head 27.17; eye 9.71; snout 5.78; maxilla 10.40; larval pectoral fin 11.00; snout to vent 49.13; snout to origin of pelvic fin 31.79; snout to origin of anal fin 54.91; distance from posterior corner of vent to origin of anal fin 4.16; depth of head at middle of eye 23.70; depth of body at middle of stomach 24.23; depth of body at vent 20.81; least depth of caudal peduncle 6.94; distance from the snout to origin of first dorsal 35.84 per cent of total length. Eye 35.74; snout 21.28; maxilla 38.30; larval pectoral fin 39.00; distance from posterior corner of vent to origin of anal fin 15.32; least depth of caudal peduncle 25.53; length of gill raker of angle of outer most gill arch 6.38; and length of longest gill filament 21.28 per cent of head length.

Although the larval finfold persists, the differentiation and development of the spines and rays of the median fins have progressed still further, there

being present 10 rudimentary spines in the first dorsal, one incipient spine and eleven rays in the second dorsal, 5 dorsal finlets, 12 incipient rays in the anal, 5 anal finlets and caudal with 16 incipient primary rays. The pectoral and pelvic fins are larval. The stomach and the intestine are slightly more elongate and the vent lies more posterior, its posterior corner being midway between tip of snout and the emarginate margin (fork) of the caudal fin. The larva has a spindle-shaped appearance. The chromatophores on the occipital region of the head show an increase in number. There are three branched chromatophores at the base of the anal fin. One melanophore is present at the lower part of the caudal peduncle, and two chromatophores at the lower base of the caudal fin. The disposition of chromatophores on the rest of the body are as shown in Fig. 2e. The lower jaw has six teeth on each side. Rudimentary gill rakers are also present.

TABLE 1. *Proportional dimensions of larvae of* Rastrelliger kanagurta.

Characters	Total length (mm)						
	1.98 Fig.1b	3.95	4.55 Fig.2a	5.40 Fig.2b	6.00 Fig.2c	6.60 Fig.2d	8.65 Fig.2e
TOTAL LENGTH: Head	4.12	4.11	3.64	3.86	3.75	3.88	3.68
Eye	9.43	8.97	8.58	9.82	10.00	10.15	10.29
Snout	22.00	17.17	18.20	15.43	15.00	14.66	17.30
Maxilla	7.92	7.90	8.27	8.57	9.23	—	9.61
Distance from snout to post. tip of vent.	2.38	2.21	2.12	2.16	2.14	2.16	2.04
Distance snout to P2	—	—	—	3.08	3.24	3.30	3.15
Distance snout to A	—	—	—	—	1.94	1.88	1.90
Depth of head through middle of eye	3.53	3.79	3.79	3.86	3.75	4.00	4.22
Greatest depth of body	3.53	3.95	3.79	3.72	4.00	4.12	4.12
Depth of body at vent	5.35	5.00	5.06	4.70	5.00	4.71	4.81
Gap between vent and A	—	—	—	—	13.33	14.66	24.03
HEAD | Eye	2.05	2.18	2.56	2.55	2.66	2.61	2.80
Snout	4.78	4.17	5.00	4.00	4.00	3.78	4.70
Maxilla	1.72	1.92	2.27	2.33	2.46	2.05	2.61
Gap between vent and A	—	—	—	—	3.55	3.78	6.53

GENERAL VARIABILITY

Colouration — Pigmentation pattern

The disposition of the melanophores and chromatophores shows slight variation from specimen to specimen. However, the basic pattern such as the post-vent row of chromatophores, their numbers and disposition with size and

so on do not differ markedly in larvae of the same size. Similarly, the appearance and disappearance of chromatophores and melanophores at different size lengths are also important. For instance it is noteworthy that the basic pattern of absence of branched chromatophores on the head until the anlages of the hypural plates are formed is seen in these larvae. However, the exact length at which this would take place may be slightly variable from larva to larva. Similarly, in a 4.5 mm (TL) larva the post-vent row of melanophores may be 12 + 1 (Fig. 2a), but in larvae of similar size length variations from 11 to 14 may be seen. With growth there is a decrease in the number of these post-vent melanophores. Similar variability is also seen in the number and disposition of the melanophores at the base of the caudal fin in the postlarvae, but the pattern shown in Fig. 2 a-e indicates the general trend. The chromatophores on the dorsum of the viscera and the intestine are in some specimens very diffuse and their number not easily countable. In some they are closely clustered appearing as dark blotches.

One notable difference seen in the larvae described by Matsui (1970) as *Rastrelliger* larvae from Thailand waters and the present specimens is the absence of melanophores at the base of the second dorsal fin in larvae even upto 8.6 mm (TL) in the latter, while in the former melanophores are present in a row at the base of the second dorsal fin in larvae from about 6 mm in length size.

Yolk-sac-absorption

Matsui (1970) comments that in *Rastrelliger* larvae the yolk-sac-absorption stage is approximately 1.3 to 1.7 mm as compared to 3.0 to 4.0 mm specimens of hatched to yolk-sac-absorption stage in *Scomber scombrus* (Sette, 1943), and similar size for *Pneumatophorus diego* (= *S. japonicus*) (Kramer, 1960). In the present collections, the smallest specimens (1.73 and 1.98 mm TL) have what appears to be remnants of yolk suggesting that the yolk-sac-absorption may be in larvae upto about 2 mm (TL) in *R. kanagurta*.

Larval Phase

The paired fins in larvae upto 8.6 mm (TL: 7.55 mm SL) do not show ossification of rays, while at this length size the median fins are fairly well developed. According to Matsui (1970), the fins are formed in a 9.6 mm *Rastrelliger* larva and "presumably the larval period ends by about 10 mm (SL)." In a 8.7 mm (SL) specimen the fins are shown as developed by Balakrishnan and Rao (1971) indicating early juvenile condition. The shape of the head and the body, particularly the dorsal and ventral profiles are markedly adult-like in this early juvenile. Their specimens have also been obtained from the south west coast of India (Vizhinjam) and from the present data it may appear that this transformation from larva to juvenile may take place at any size length of the larva over 8 mm (SL) corresponding to about 9.5 mm (T.L.).

Teeth

Larva 3.38 mm (TL: 3.25 mm SL) has only one tooth on each side of the upper and lower jaws, while by about 4.5 mm (TL: 4.37 mm SL) their number increases to three teeth on each side of upper jaw and four on each side of lower jaw, the latter increasing to about 6 teeth when the larva is 8.6 mm (TL). According to Matsui (1970) from about 2 mm two teeth are present on the mandible and two on the upper jaw and by 4 mm the number increases to 4 on the upper and 6 on the lower jaw in *Rastrelliger* larvae from Thailand. Variability in the number of teeth in relation to size length may be expected in larvae from different geographical areas and at this stage it is difficult to say whether this has any specific significance.

Myomeres and Myosepta

The number of myosepta in the prolarvae are variable until the full complement of myomeres are formed by the time the larva attains about 3 mm (TL). Matsui (1970) remarks that by 4 mm in the Thailand specimens the myomeres grow more oblique with zigzaging present in most of the segments. Such a condition is seen in the present specimens only by about 5.4 mm (TL). It is significant that the bending of the notochord and the simultaneous formation of the hypural plates also coincide with the zigzaging of the myomeres. In the larvae of *R. kanagurta* incidentally early indications of the bending of the notochord is seen by the time that the larva is 4.5 mm (TL: 4.37 mm SL). For the Thailand specimens Matsui (1970) mentions that the notochord bends and the caudal fin forms between 3 and 5 mm. In the present specimens the hypural plates are formed when the larva is about 6 mm (TL).

Ossification of caudal fin rays

Among the paired and median fins it is the caudal fin that shows more rapid development and the earliest indication of ossification of the rays. This is evident in larvae about 5 mm in TL and upwards and by the time the larva is about 8.6 mm most of the caudal rays are ossified. This and the zigzaging development of the myomeres are indications of better and stronger swimming capabilities of the larvae. This may also account for the absence of larvae larger than about 8.8 mm (TL) in the vertical tows taken with the IOS Net in the present collections hauled at about 40-45 m / minute. Regional differences may be present in the caudal fin development as according to Matsui (1970) in the Thailand specimens the principal caudal rays ossify between 4 and 5 mm in length size.

Remarks

Some of the variations noted between the larvae described from the Thailand waters and the present specimens are noteworthy. Matsui (1970) rightly refrained from giving a specific name to the *Rastrelliger* larvae especially as three species are known from the Thailand waters and he has shown the great similarity between the early juveniles of *R. kanagurta* and *R. brachysoma*. It may

be pointed out that when compared to the present specimens the occurrence of a row of melanophores along the second dorsal base in the Thailand specimens of about 6.9 mm is significant. In the present collections specimens upto 8.8 mm (TL) do not have melanophores along the base of the second dorsal fin. It may be worthwhile seeing whether this may be an identifying character for separating larvae of this size length of *R. kanagurta* and *R. brachysoma*. In this context, all such small differences noted between larvae from these two areas assume significance.

It may not be out of place to mention here that Peter's (1970) description of larvae of *Rastrelliger* are based on three specimens 2.7, 3.1, and 5.3 mm obtained from 22°22'N 60°05'E; 16°37'N 41°09'E; and 18°15'N 87°48'E respectively. He has opined that *Rastrelliger kanagurta* is the dominant species in the Indian waters, "It is therefore to be expected that the present series belong to *Rastrelliger kanagurta*." While this arguement may not be quite convincing for justifying specific identification of the three larval specimens, it may also be mentioned here that there are considerable discrepancies between the drawings of the three larvae and the descriptions of the same given by him. A re-examination of these larvae may be necessary for clarifying their specific identity as well as correcting the several discrepancies.

Incidentally it may be mentioned here that a larva of *Rastrelliger*, very much akin to that being presently reported from along the south west coast has been collected from the Madras coast recently (Girijavallabhan and Gnanamuttu, 1974) and is being described as *Rastrelliger* sp.

These investigations clearly indicate the more widespread occurrence of mackerel larvae in the Indian Seas, particularly in the continental shelf waters.

Distribution of Larvae

The 92 stations covered during the cruises of *R. V. VARUNA* in May 1964 were between 7°N to 13°N and 74°40'E to 77°25'E, and 54 out of 185 plankton hauls yielding 362 larvae were from 38 positive stations, the maximum numbers occurred between 9°N and 10°N in the continental shelf waters (Fig. 3* and Tables 2 and 3). Most of the larvae were obtained at stations in the depth zone 30 to 80 metres in the shelf area. Interestingly enough Matsui (1970) also records catching most of the *Rastrelliger* larvae in seas shallower than 90 metres indicating that the nursery area of mackerel larva is coastal. The present observations are also in conformity with this as will be seen from the data presented in Table 3.

* The insert drawings in the figure indicate also the frequency of occurrence of positive stations in relation to sounding depth; numerical abundance of larvae in relation to sounding depth; percentage of occurrence of larvae latitude-wise; occurrence in relation to size length. Different symbols are given for stations of different cruises as well as for day and night stations.

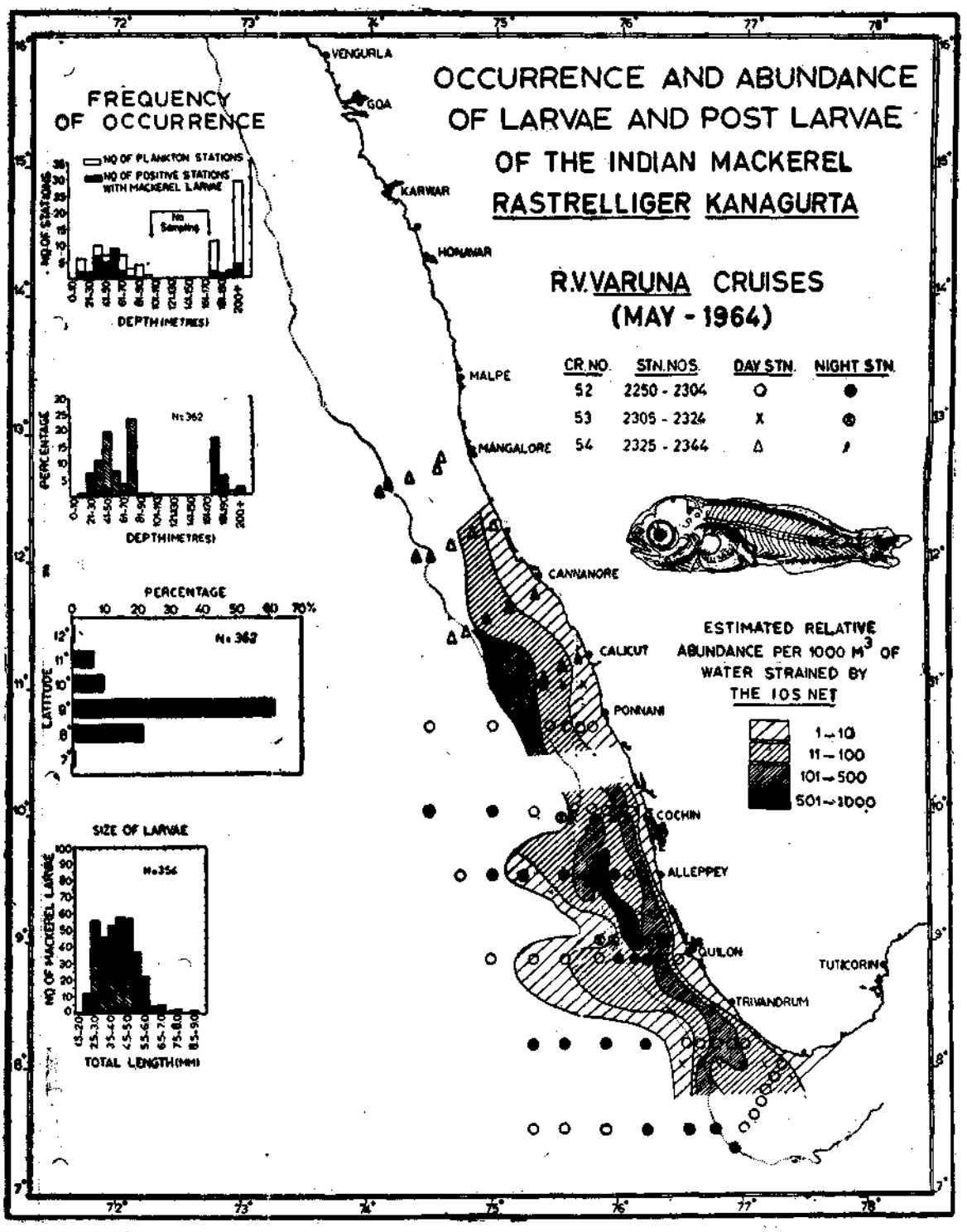

FIG. 3. Map showing; the occurrence, distribution and abundance of larave of the Indian mackerel *Rastrelliger kanagurta* (Cuvier) along the south west coast of India.

(*See footnote on page* 244)

TABLE 2. *Abundance of mackerel larvae at the different latitudes as seen from collections made during May,* 1964.

Latitude	Number of plankton hauls	Number of positive hauls	Number of specimens in cruises			Total number of mackerel larvae	per cent
			V 52	V 53	V 54		
7° N — 8° N	24	1	1	—	—	1	0.28
8° N — 9° N	48	18	74	3	—	77	21.27
9° N — 10° N	29	13	151	73	—	224	61.88
10° N — 11° N	42	11	17	17	—	34	9.39
11° N — 12° N	26	9	—	11	12	23	6.35
12° N — 13° N	16	2	—	—	3	3	0.83
Total	185	54	243	104	15	362	

TABLE 3. *Occurrence of mackerel larvae in the continental shelf and oceanic waters.*

Sounding depth at stations (metres)	Total No. of stns. (May,1964)	Number of positive stations	Number of positive hauls	Total No. of mackerel larvae	Total length	
					Range	Mean
0 — 10	—	—	—	—	—	—
11 — 20	6	2	3	7	2.5 — 3.6	2.90
21 — 30	2	1	1	2	2.7 — 3.2	2.95
31 — 40	10	7	12	39	2.1 — 8.8	4.19
41 — 50	7	5	8	36	1.73— 6.3	3.41
51 — 60	9	8	10	86	2.1 — 7.6	4.81
61 — 70	7	2	3	11	3.0 — 6.0	3.42
71 — 80	3	3	4	85	3.5 — 7.0	4.48
81 — 90	4	1	1	1	6.5	6.50
91 — 100	1	1	1	1	3.0	3.00
101 — 120	No stations					
161 — 170	No stations					
171 — 180	11	2	3	63	3.1 — 5.6	4.66
181 — 190	1	1	2	20	4.3 — 7.2	5.17
191 — 200	2	1	2	3	4.1 — 5.2	4.37
201 + (Outside the continental shelf)	29	4	4	8	3.2 — 5.2	4.17
Total	92	38	54	362*	1.73— 8.8	4.16

* Eight of these larvae were damaged and they have not been considered for data given in Tables 4 and 5.

TABLE 4. *Number and size of larvae* R. kanagurta *collected at each station.*

R. V. *VARUNA* Station No.	No. of hauls	Number of specimens	Total length	
			Range (mm)	Mean (mm)
2252	1	1	7.0 —	7.0
2253	1	1	6.5 —	6.5
2261	1	1	5.4 —	5.4
2262	1	1	4.9 —	4.9
2263	2	13	3.0 — 6.0	3.64
2266	1	1	2.9 —	2.9
2282	2	3	4.1 — 5.2	4.37
2285	2	8	2.8 — 4.2	3.16
2286	2	3	2.6 — 3.0	2.83
2287	1	2	2.7 — 3.2	2.95
2288	2	20	1.73— 3.4	2.72
2289	1	1	5.5 —	5.5
2290	2	9	3.0 — 6.0	4.26
2291	2	20	4.3 — 7.2	5.17
2292	1	4	3.8 — 5.1	4.52
2294	1	1	3.2 —	3.2
2300	2	62	3.1 — 5.6	4.22
2301	2	81	3.9 — 7.0	5.02
2302	2	5	5.0 — 6.5	5.84
2303	1	1	5.7 —	5.7
2305	1	2	2.5 — 3.2	2.85
2307	1	1	3.0 —	3.0
2310	1	1	4.0 —	4.0
2312	2	55	2.1 — 4.3	3.29
2313	2	10	2.1 — 8.8	6.01
2314	1	2	2.8 — 3.6	3.2
2315	2	5	2.5 — 2.8	2.6
2316	1	2	4.2 — 4.9	4.55
2317	1	9	2.6 — 6.0	3.96
2318	1	1	5.1 —	5.1
2320	1	2	4.7 — 5.2	4.95
2321	1	9	3.3 — 5.0	4.4
2322	2	2	2.8 — 5.8	4.3
2326	1	2	3.0 — 3.3	3.15
2332	1	1	3.5 —	3.5
2337	1	1	3.0 —	3.0
2342	2	8	2.6 — 6.3	3.97
2343	2	3	3.3 — 4.0	3.7
Total Station 38	54	354*		

* Eight out of the 362 specimens were damaged while measurements were taken and hence not included in this table.

The length measurements of 354 undamaged larvae (Table 4) show that the size of the larvae did not generally vary much at each of the positive stations. Most of the larvae in the collections were between 2.5 and 6.0 mm (TL) (Table 5). The larvae at this size length have not developed the fins and musculature sufficiently well to enable them to cover long distances by active swimming. On the other hand it is very likely that the areas from where the larvae have been collected also represent the spawning grounds of the Indian mackerel along the south west coast of India. Passive transport of prolarvae and early post-larvae over long distances may not take place. If this be so, it is interesting to note that the spawning grounds of the Indian mackerel along the south west coast are fairly extensive, with the shelf area between Cochin and Quilon assuming greater importance.

TABLE 5. *Size-wise frequency of occurrence of mackerel larvae obtained during three cruises of* R. V. *VARUNA in May*, 1964.

Total length (mm)	Cruise numbers V 52	V 53	V 54	Total number of larvae*
1.73 — 2.00	2	—	—	2
2.01 — 2.50	5	7	—	12
2.51 — 3.00	22	25	5	52
3.01 — 3.50	20	23	4	47
3.51 — 4.00	32	17	3	52
4.01 — 4.50	47	12	—	59
4.51 — 5.00	—	—	—	—
5.01 — 5.50	36	3	—	39
5.51 — 6.00	19	3	—	22
6.01 — 6.50	4	—	1	5
6.51 — 7.00	2	3	—	5
7.01 — 7.50	1	—	—	1
7.51 — 8.00	—	2	—	2
8.01 — 8.50	—	—	—	—
8.51 — 9.00	—	1	—	1
Total	238	101	15	354

* Eight out of the 362 specimens were damaged while measurements were taken and hence not included in this table.

The occurrence of larvae in relation to the time of collection give some interesting information which should be of importance in planning larval surveys. More larvae were obtained between 19.30 and 05.00 hours when on an average 6.91 m^3 of water had to be strained by the IOS Net (Filteration efficiency 96%) for obtaining one mackerel larva. Correspondingly the figures were 11.43 m^3 of water for daytime (06.30 to 18.00 hours) and 23.10 m^3 water for twilight (10.00-19.30 and 05.00-06.30 hours) (Table 6).

TABLE 6. *Occurrence of larvae in relation to time of collection.*

Time of day	Cruise No.	Number of mackerel larvae	m3 of water filtered by IOS Net *	m3 of water filtered per larva captured	Average of three cruises (m3 of water filtered|larva captured)
Day	V 52	26	264.0	10.15 m3|larva	11.43 m3|larva
0630 — 1800	V 53	19	230.0	12.10 "	
Hours	V 54	2	43.2	21.60 "	
Twilight	V 52	31	715.2	23.07 "	
1800 — 1930	V 53	15	297.6	19.84 "	23.10 m3|larva
0500 — 0630	V 54	2	96.0	48.00 "	
Hours					
Night	V 52	186	1240.6	6.66 "	
1930 — 0500	V 53	70	480.0	6.85 "	6.91 m3|larva
Hours	V 54	11	124.8	11.34 "	

* Filteration efficiency of IOS Net considered as 96%.

For understanding the hydrological conditions of the shelf and adjacent oceanic waters from where mackerel larvae have been collected, data from stations along three Sections have been examined (Fig. 4). Of these, the Section just south of Quilon and the one off Cochin (Stations 2287-2295, and 2315-2319 respectively) have been taken for understanding the conditions just north and south of an area of greater abundance of mackerel larvae for which the Section just north of Quilon (Stations 2310-2314) may be representative. In general it may be seen that outside the shelf waters the upper limit of the thermocline is about 50 to 60 m and the oxygen deficient layer starts at the top of the thermocline and extends downwards to about 150 m. In the Sections south of Quilon and off Cochin it may be seen that the isothermal mixed layer is absent over the shelf and cold water intrusions over the shelf are seen. An upward slope of the isolines of dissolved oxygen are also seen in these two Sections. These may be indicative of the changes at the commencement of coastal upwelling. However, in the Section north of Quilon, the mixed layer is observed in the major part of the continental shelf. The distribution of salinity is also uniform over the shelf with high values in contrast to the other two Sections. A similar trend of high dissolved oxygen content over the continental shelf in this Section is seen indicating that lateral movements in the area are negligible as compared to the Sections off Cochin and south of Quilon. At Station 2312 of the Section north of Quilon where an estimated number of over 500 larvae per 1000 m^3 of water strained were obtained, the temperature, salinity and dissolved oxygen content of the water which were all relatively high were for surface, 10 m and 30 m as follows:

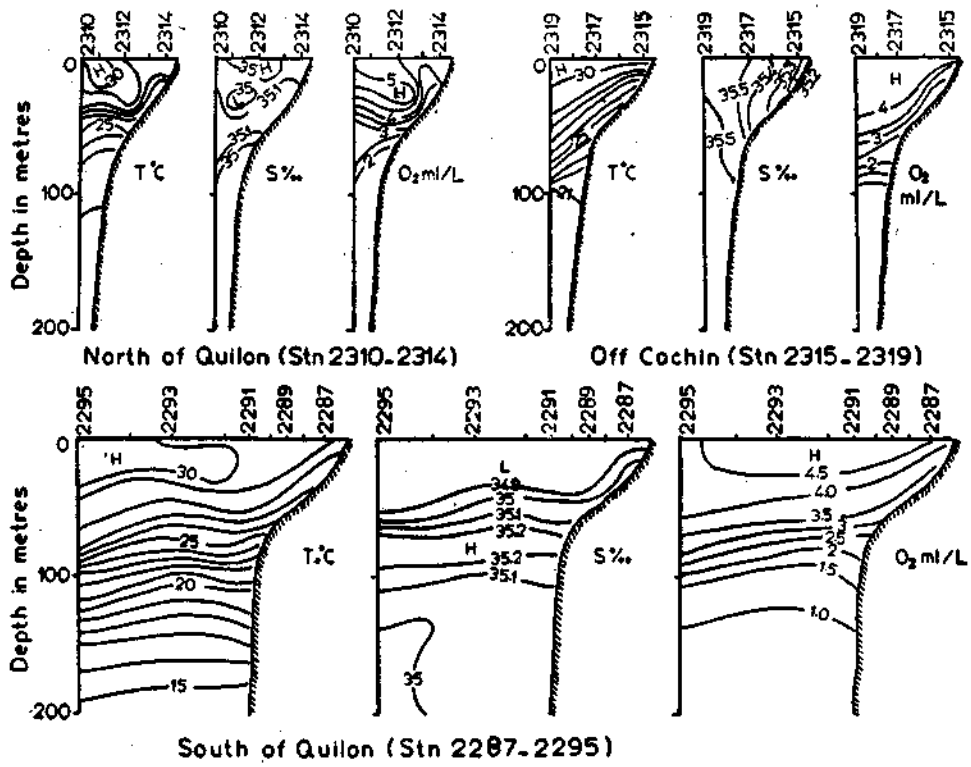

FIG. 4. Distribution of Temperature, Salinity and Dissolved Oxygen across three Sections along the south west coast of India from where mackerel larvae have been obtained.

Depth (Metres)	Temperature (°C)	Salinity (‰)	Dissolved Oxygen (ml|l)
Surface	28.6	35.13	4.50
10	29.89	35.12	4.80
30	29.50	35.08	5.55

An attempt was made to see the Temperature — Salinity — Dissolved Oxygen relationship to the occurrence of mackerel larvae by considering the values for two of these parametres at a time in relation to the positive stations for Surface, 10 m and 30 m depths. No closing nets were used for making stratified collections, but it is presumed that most of the larvae may occur in the surface and immediate subsurface waters above 30 metres. In fact, Kramer (1960) reports that more than 99 per cent of the Pacific mackerel larvae were taken above 50 metres, and over 80 per cent above 23 metres, with none collected below 66 metres. While recognising the paucity of information about the

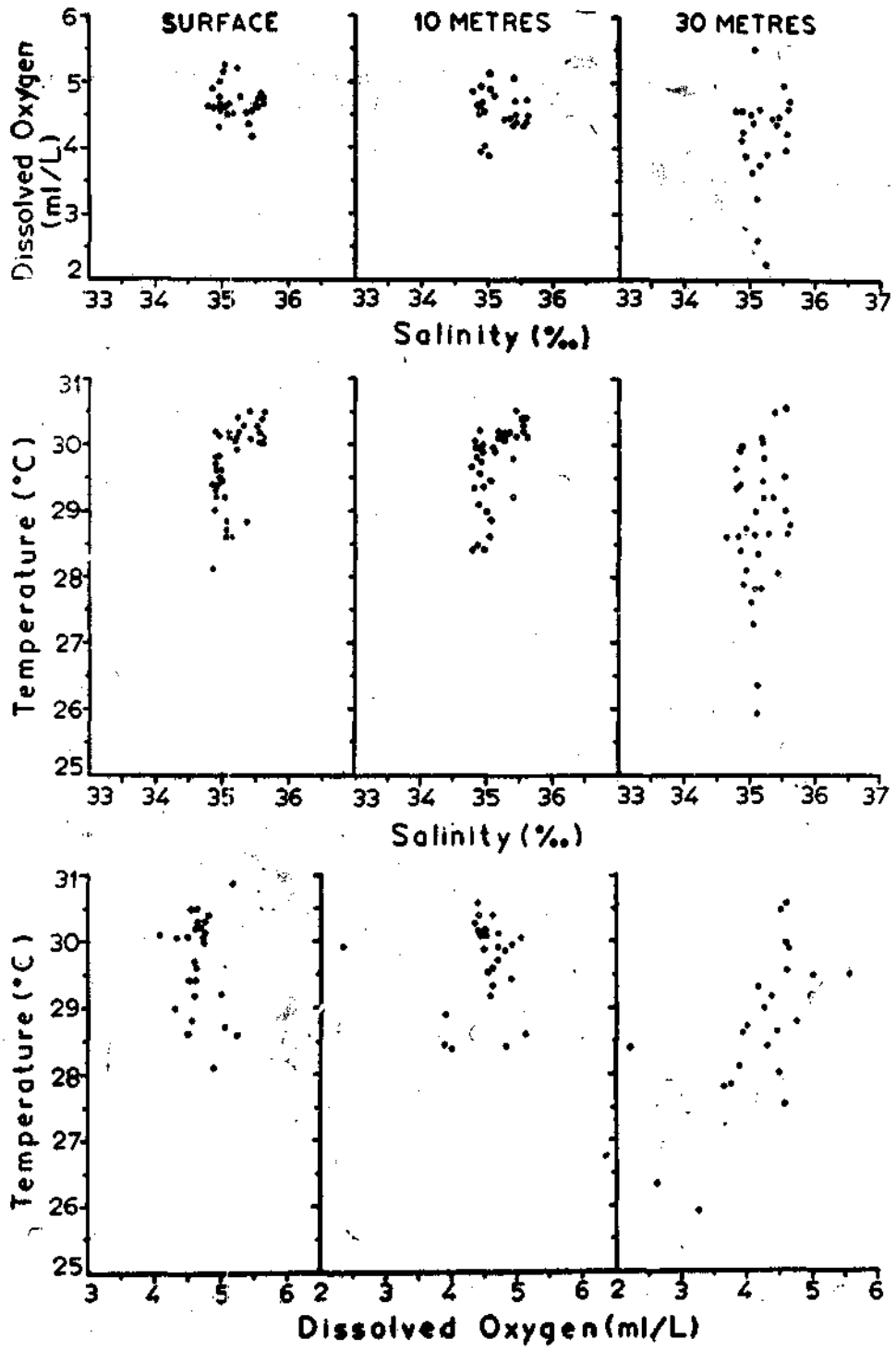

FIG. 5. The occurrence of positive stations ( ) from where mackerel larvae have been obtained shown in relation to Temporature-Dissolved Oxygen; Temperature — Salinity; and Dissolved Oxygen-Salinity, for Surface, 10 m and 30 m depths.

bathymetric distribution of the larvae of *R. kanagurta*, the range for three parametres for three depths (Fig. 5) is as follows for the positive stations:

Depth (Metres)	Temperature (°C)	Salinity (‰)	Dissolved Oxygen (ml|l)
Surface	28.2-30.8	34.85-35.7	4.2-5.25
10	28.4-30.6	34.8 -35.8	2.3-5.15
30	25.95-30.6	34.74-35.7	2.2-5.55

The temperature and dissolved oxygen values at 30 m and 10 m respectively evince wider fluctuations. However, as will be seen from Fig. 5, most of the positive stations indicate higher values for these parameters. A proper evalution of the occurrence of mackerel larvae in relation to environmental conditions will be possible when the occurrence of larvae in the plankton in time and space is studied also taking into consideration stratified collections for having more precise information on the bathymetric distribution and abundance of the larvae.

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