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ON THE LARVAL AND POSTLARVAL DEVELOPMENT AND DISTRIBUTION OF THE MESOPELAGIC FISH *VINCIGUERRIA NIMBARIA* (JORDAN AND WILLIAMS) (FAMILY GONOSTOMATIDAE) OFF THE WEST COAST OF INDIA AND THE LACCADIVE SEA*

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INTRODUCTION

THE Research Vessel *Varuna* commenced working in the Indian Seas from January 1962 and by the end of December 1963 had completed 44 cruises in the Arabian Sea, Central Indian Ocean north of the Equator, and the Bay of Bengal. Routine plankton collections made at the various stations, especially in the oceanic waters off the west coast of India showed the fairly widespread occurrence of the larval stages of some species of bathypelagic fishes, one of which, *Vinciguerria nimbaria* (Jordan and Williams) is dealt with in this account. The station details, number and sizes of larvae obtained, and other particulars for the positive stations are indicated in Table 8.

The species at present referable to the genus *Vinciguerria* Jordan and Evermann (1896) have been at one time or other described under the genera or subgenera *Poweria* Bonaparte (1841), *Ichthyococcus* Bonaparte (1841), *Scopelus* Cuvier (1817), *Gonostoma* Rafinesque (1810), *Maurolicus* Cocco (1838), and *Zalarges* Jordan and Williams (*in* Jordan and Starks, 1896). Ahlstrom and Counts (1958) indicated the desirability of retaining the familiar generic name *Vinciguerria* proposed by Jordan and Evermann (1896), but first recorded by Goode and Bean (1895, p. 513) over the earlier proposed lesser known name *Poweria* Bonaparte (1841) [Subgenus of *Ichthyococcus*, with *I.* (*Poweria*) *poweria* as the type species], with which course we are in agreement.

Background information as to the species of *Vinciguerria*, especially those recorded from the Indian Ocean is necessary for the proper identification of the larvae. The works of Jespersen and Taning (1919, 1926), Norman (1930), Horsburgh (1935), and Ahlstrom and Counts (1958) show that only four species of *Vinciguerria* may be recognised as follows :

1. *Vinciguerria attenuata* Jordan and Evermann (1896) : From Mediterranean and Atlantic. Synonym : *Scopelus tenorei* Valenciennes.
2. *Vinciguerria lucetia* (Garman) (1899) : From Atlantic and Indo-Pacific. Synonym : *Vinciguerria pacifici* Hildebrand (1946). Doubtful synonym : *Narooma benefica* Whitley (1935).

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3. *Vinciguerria nimbaria* (Jordan and Williams) (1896). From Mediterranean, Atlantic and Indo-Pacific. Synonym : *Vinciguerria sanzoi* Jespersen and Taning (1919). Doubtful synonym : *Gonostoma raoulensis* Waite (1910).
4. *Vinciguerria poweriae* (Cocco) (1838). From Mediterranean, Atlantic and Eastern Pacific.

While drawing attention to discrepancies in the original description of *Vinciguerria lucetia* and of other species mentioned above, Ahlstrom and Counts (1958) have discussed the nomenclature and synonyms of *V. lucetia, V. poweriae,* and *V. nimbaria,* the three species known to occur in the Eastern Pacific.

There is a paucity of information on the occurrence and distribution of species of *Vinciguerria* in the Indian Ocean, and only stray records are available. *V. lucetia* has been recorded by Brauer (1906) from Off New Amsterdam Island ; Off Sumatra ; Bay of Bengal ; from between Ceylon and Chagos Archipelago and Off Zanzibar. Weber (1913) recorded this species from the Molucco Passage (Indonesian waters) and Smith (1948, 1961) from Delagoa Bay, South Africa.

Norman (1939) recorded *V. nimbaria* from the Arabian Sea (23° 2′ 48″N, 64° 31′ 54″E). It has also been reported by Smith (1949, 1961) as *V. sanzoi* from East London to Delagoa Bay, South Africa.

In a ' Checklist ' and an ' Aid ' to the identification of the Clupeiform fishes of India, Misra (1947, 1953) has listed ' *Vinciguerria lucetius* (Garm.) ' and ' *Vinciguerria nimbaricus* (Jordan and Williams) ' from the Indian Seas and has separated the two species on the presence (*V. lucetius*) or absence (*V. nimbaricus*) of the symphysial photophores. This is misleading, as our examination of good series of specimens of *V. nimbaria* as well as the works of Norman (1930), Horsburgh (1935), and Ahlstrom and Counts (1958) clearly indicate that *V. lucetia* and *V. nimbaria* are both characterised by the presence of a pair of symphysial photophores, while *V. attenuata* and *V. poweriae* are wanting in this.

The larvae of species of *Vinciguerria* have not been described from Indian Seas.

Ahlstrom and Counts (1958) found it rather difficult to give very clear-cut differences between early stages of *V. lucetia* and *V. nimbaria* from the Eastern Pacific. Differences are noticeable from the prometamorphic stage onwards, and are chiefly seen in the number of gill rakers, lateral photophores and anal finrays. Body proportions show considerable overlap in the two species. The salient differences as mentioned by these authors are given in the following table (Table 1) as it will be useful for later comparisons with materials from the Indian Seas.

TABLE 1

Characters	*V. nimbaria*	*V. lucetia*
1. Gill rakers (lower limb)	13 - 15	16 - 23
2. Photophores : Lateral OV	13 - 14 (13.8 Av.)	10 - 13 (11.33 Av.)
Ventral IV	16 - 17 (16.08 Av.)	13 - 16 (14.33 Av.)
3. Total photophores per side	84 - 87 (84.35 Av.)	78 - 86 (81.29 Av.)
4. Anal fin rays	14 - 15 (14.64 Av.)	13 - 17 (15.14 Av.)

We have followed the key characters given by Ahlstrom and Counts (1958) in identifying the larvae of *V. nimbaria* from Indian Seas. Our study also shows considerable overlap in meristic and morphometric characters between successive metamorphic stages in *V. nimbaria.*

Material

Larvae of *V. nimbaria* were present in 111 plankton samples from 83 stations out of a total of 1728 samples examined from 912 stations worked during the R.V. *Varuna* cruises off the west coast of India, the Laccadive Sea, and the Central Indian Ocean north of the Equator. The samples contained a total of 526 specimens of *V. nimbaria* in different stages of larval and postlarval development (Table 8).

Methods of Collection

The Indian Ocean Standard net was used for vertical hauls from 200 m. to surface or from 5 m. above bottom to surface when depth was less, from Cruise 30 onwards. Prior to that, during the first 16 cruises (from Stn. 690-1183) a Nansen Net of 70 cm. ring diameter and 290 cm. length with mesh size 0.203 mm. (about 5 mesh per sq. mm,) was used for vertical hauls from 100 m. to surface or from 5 m. above bottom to surface when depth was less. From cruise 17-27 (Stn. 1184-1714) a net with 100 cm. ring diameter and 5 metres in length of terylene material and mesh size 0.33 mm. was used for vertical hauls from 200 m. to surface or from 5 m. above bottom to surface when the depth was less. During cruises 18 to 40 (Stn. 1229-1995) nets with 50 cm. ring diameter and 2 metres long of cotton mosquito netting having mesh diameter 1.5 mm. were used on several occasions for taking simultaneous stratified oblique tows of 15 minutes duration from 30, 50, 75, 100, and 200 metres or simultaneous stratified vertical tows to surface from these depths. These different nets used are indicated in Table 8.

Terminology and Details of Stages Recognised from Early Larvae to Adult in *Vinciguerria nimbaria*

As in some Clupeiform fishes, marked changes attributable as metamorphosis is seen in the larval development of species of *Vinciguerria.* Often these changes are not related to the length of the specimen, but the time factor (duration of larval stage) probably plays an important part. Ahlstrom and Counts (1958) recognised six stages in the postembryonic development of *V. lucetia.* It is seen from our examination of material of *V. nimbaria* that these stages are useful for assigning the growth stages of this species as well for descriptive purposes.

We have also found considerable overlap in the size ranges at which the various transitions take place, but the occurrence of salient characters, such as, the time of appearance of photophores, change in shape of eye, changes in body profile, etc. show differences. The terminology given below adopted from Ahlstrom and Counts (1958) is not intended to be general. This is applicable to species of this genus and clearly separates growth stages and is very evident when large series of specimens are examined as in the present case.

(i) *Larval Stage :* Postembryonic to earliest indication of photophore formation. (This larval stage may be subdivided into an early and late

TABLE 2

Average Body Measurements and Average Meristic counts of the larval stage and metamorphic stages of **Vinciguerria nimbaria**

Standard length (Range)** mm.	No. of specimens examined	AVERAGE BODY MEASUREMENTS (mm.) Standard lenth (mm)+	Head length	Depth at P1	Eye Diameter	Snout to P2	Snout to D1	Snout to A	AVERAGE MERISTIC COUNTS Dors	Anal	Pectoral	Caudal fin: Principal rays	Caudal fin: Secondary rays: Dorsal	Caudal fin: Secondary rays: Ventral
1. Larval Stage														
4.0-4.4	1	..	..	..	..	..	..	..	L(1)	L(1)	L(1)	L(1)	L(1)	L(1)
4.5-4.9	2	4.9(2)	0.85(2)	..	0.3(2)	..	3.3(1)	3.75(1)	L(2)	L(2)	L(2)	L(2)	L(2)	L(2)
5.0-5.4	2	5.25(2)	0.86(2)	..	0.32(2)	..	3.1(2)	3.6(2)	L(2)	L(2)	L(2)	L(2)	L(2)	L(2)
5.5-5.9	9	5.7(9)	1.0 (8)	0.25(1)	0.36(6)	..	3.75(7)	4.4(5)	L(1), 11(3)	L(9)	L(9)	L(9)	L(9)	L(9)
6.0-6.4	11	6.17(11)	1.21(11)	0.7(1)	0.36(10)	..	4.18(9)	4.90(9)	L(1), 11(10)	L(8), 13(3)	L(10)	L(1), 18(7)	L(1), 2.6(6)	L(1), 3.3(6)
6.5-6.9	11	6.7(11)	1.37(8)	0.6(1)	0.37(9)	..	4.45(8)	5.26(8)	12(11)	L(3), 12(8)	L(11)	17.2(8)	L(2), 2.5(5)	L(2), 2.6(6)
7.0-7.4	7	7.2(7)	1.49(5)	..	0.37(4)	..	4.75(2)	5.4(2)	12(4)	12(4)	L(4)	17(4)	3(2)	2.5(2)
7.5-7.9	9	7.6(9)	1.5(6)	0.6(1)	0.41(4)	..	5.07(4)	5.92(4)	12.4(7)	L(1), 11.6(5)	L(9)	16.5(6)	3.5(4)	3(4)
8.0-8.4	7	8.2(7)	1.6(7)	0.7(1)	0.5(5)	5.8(1)	5.24(5)	6.25(6)	12(5)	11.6(6)	L(7)	16.5(4)	3.5(4)	2.75(4)
8.5-8.9	12	8.7(12)	1.69(9)	..	0.45(9)	..	5.78(8)	6.8(8)	12.3(9)	12.36(11)	L(12)	17.1(11)	3.2(9)	3.0(9)
9.0-9.4	9	9.2(9)	1.81(9)	0.8(1)	0.47(8)	..	5.77(8)	6.71(8)	13(5)	13.2(5)	L(9)	17.5(4)	3(3)	2(3)
9.5-9.9	6	9.63(6)	1.84(3)	..	0.6(2)	..	5.72(3)	6.73(3)	12.8(5)	12.5(5)	L(6)	17(2)	4.5(2)	4(2)
10.0-10.4	2	10.5(2)	2.1(2)	0.7(1)	0.6(2)	..	6.5(1)	7.5(1)	12.5(2)	13(2)	L(2)	16.5(2)	4(2)	4(2)
10.5-10.9	5	10.74(5)	2.07(4)	0.8(1)	0.52(4)	..	6.8(3)	7.9(3)	13(5)	13.6(5)	L(5)	18.5(4)	3.5(4)	4(4)
11.0-11.4	7	11.23(7)	2.45(4)	0.95(2)	0.61(4)	6.2(1)	7.56(4)	8.57(4)	12.7(7)	12.1(6)	L(7)	17.4(5)	4.8(5)	4.2(5)
11.5-11.9	1	11.5(1)	..	..	..	..	..	..	11(1)	11(1)	L(1)	17(1)	4(1)	5(1)
12.0-12.4	6	12.1(6)	2.62(4)	0.9(1)	0.6(2)	..	7.35(2)	8.55(2)	13(5)	12.5(6)	L(6)	18(5)	5(5)	3.8(5)
13.5-13.9	1	13.6(1)	2.5(1)	..	0.65(1)	..	..	..	14(1)	14(1)	L(1)	18(1)	5(1)	4(1)
2. Prometamorphic Stage														
12.0-12.4	1	12.4(1)	..	..	..	..	..	..	13(1)	13(1)	L(1)	18(1)	4(1)	4(1)
12.5-12.9	..	..	..	..	..	..	..	..	..	..	..	..	..	..
13.0-13.4	3	13.25(3)	3.3(1)	1.3(1)	0.8(1)	..	7.9(1)	10.2(1)	13.5(2)	13.5(2)	L(3)	18(1)	6(1)	4(1)
13.5-13.9	1	13.7(1)	3.2(1)	2.0(1)	1.0(1)	6.5(1)	7.8(1)	8.7(1)	14(1)	14(1)	L(1)	18(1)	4(1)	4(1)
14.0-14.4	7	14.3(7)	3.24(7)	1.8(4)	0.84(7)	6.7(2)	8.4(4)	9.9(4)	13.5(6)	13.5(6)	L(7)	18.25(4)	6.4(4)	4.5(4)
14.5-14.9	3	14.6(3)	4.03(3)	2.2(3)	1.27(3)	7.2(3)	8.2(3)	9.7(3)	13(2)	13.5(2)	L(3)	18.5(2)	6.5(2)	4.5(2)
15.0-15.4	1	15.0(1)	3.3(1)	1.5(1)	..	7.2(1)	8.3(1)	10.1(1)	13(1)	13(1)	L(1)	17(1)	8(1)	6(1)
3. Midmetamorphic Stage														
12.5-12.9	1	12.9(1)	..	..	..	..	..	..	13(1)	13(1)	..	17(1)	6(1)	5(1)
4. Postmetamorphic Stage														
14.0-14.4	1	14.2(1)	3.8(1)	2.3(1)	1.1(1)	6.9(1)	7.9(1)	9.5(1)	14(1)	14(1)	PL(1)	18(1)	7(1)	5(1)
14.5-14.9	1	14.5(1)	4.3(1)	2.4(1)	1.3(1)	7.0(1)	7.8(1)	10.1(1)	14(1)	14(1)	PL(1)	18(1)	7(1)	5(1)

(**) In the larval stage upto about 7.4 mm. as the larval caudal fin is not differentiated, total length has been taken. (+) Upto 7.4 mm. total length is taken. (L) larval fin. (PL) partially larval fin where the fin rays have started differentiating. In the table the number of specimens for which each character has been examined is given in paranthesis.

stage, the former in which the caudal fin is not yet well differentiated as may be seen in specimens of *V. nimbaria* up to about 7 mm. in total length.)

(ii) *Prometamporhic Stage :* The white photophore stage.

(iii) *Midmetamorphic Stage :* Stage of rapid change in body proportions including a marked increase in the depth and changes of the eye shape from oblong to round.

(iv) *Postmetamorphic Stage :* From the time that the eye becomes round until the end of photophore formation and the pigmentation are complete.

(v) *Juvenile :* Between postmetamorphic stage and sexual maturity.

(vi) *Adult :* Sexually mature individuals.

The above arbitrary divisions while applicable in the case of *V. nimbaria*, do not strictly correspond with the terminology of the early stages of fishes suggested by Hubbs (1943). What Ahlstrom and Counts (1958) have indicated as 'Larval Stage' would include the 'Prolarva' and 'Postlarva' (early) as given by Hubbs. In our material the stage corresponding to the prolarva in which the larva still retains the yolk is not present and the smallest larva examined is 4.3 mm. in total length. However, Ahlstrom and Counts (1958) have reported on very early post embryonic stage of *V. lucetia* under 'Larval Stage'. The prometamorphic, midmetamorphic and postmetamorphic stages would correspond to the 'Postlarva' (late) of Hubbs (1943). During the postmetamorphic stage, most of the adult characters are developed giving the essential appearance of the adult, although the normal adult complement of meristic characters may not be present. The 'Juvenile' mentioned above may correspond with the 'Juvenile' and higher stages upto sexual maturity (young-of-year ; yearling ; etc.,) as given by Hubbs (1943). As it is, we have no idea as to the age at sexual maturity in *V. nimbaria*, but it is presumed that the intervening period between juvenile stage and sexual maturity may be less than one calendar year.

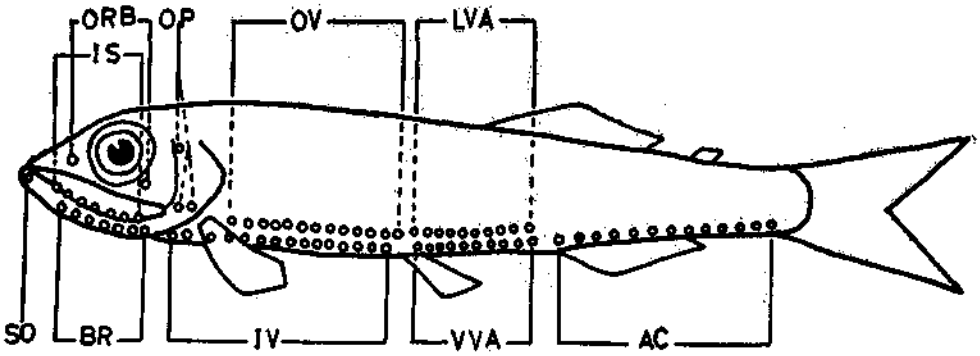

FIG. 1. Schematic drawing of *Vinciguerria nimbaria* (Jordan and Williams) showing disposition of photophores. For photophore terminology refer text.

METHODS OF MEASUREMENTS OF BODY PARTS AND MAKING COUNTS

The measurements of the larvae were taken with ocularmicrometer and the metamorphosing stages and juveniles with a dial calliper measuring to the nearest tenth of a millimetre. Specimens of the different stages were cleared and Alizarine stained to check up the accuracy of the meristic counts.

Total length : Measured from tip of snout to tip of larval caudal (in larvae upto about 7 mm.) and in later stages up to the tip of the upper caudal lobe.

Standard length : Measured from the tip of the snout to the base of the caudal fin once the caudal fin is well defined.

Eye diameter : Since in early larval stages the eye is oblong and slightly pedunculate, the vertical diameter is taken upto the prometamorphic stage. In the midmetamorphic and later stages when the eye assumes the normal round shape, the horizontal diameter between the free orbital margin is taken.

Standard methods are used for measuring other body parts.

Fin rays : Fin ray counts were not taken for partially larval fins in the larval stage. In the case of caudal fin, both primary and secondary rays were counted under magnification. However, Alizarine stained specimens indicate slightly higher counts for secondary caudal rays in *V. nimbaria* (Table 4). Such differences were not noticeable in other fin ray counts.

PHOTOPHORE TERMINOLOGY

The normal complement of photophores as seen in the adult is not met with in the metamorphosing stages. The typical arrangement of photophores in adult *V. nimbaria* is shown in Fig. 1. The photophores are generally paired and for convenience the counts are made from one side of the body in the metamorphosing stages.

We have followed the terminology used by Ahlstrom and Counts (1958) for the photophore groups and these are as follows :

SO — Symphysial

ORB — Orbital

OP — Opercular

BR — Branchiostegal

IS — Isthumian

OV — Lateral photophore group from operculum to ventral fin.

LATERAL VA (LVA) — Lateral group extending from ventral fin to origin of anal fin.

VENTRAL VA (VVA) — Ventral group between ventral fins and origin of anal fin.

IV — Ventral body photophores between isthmus and ventral fins.

AC — Photophore group between origin of anal fin and base of caudal fin.

Occasionally a single photophore (not paired) may be present in the group between the origin of the anal fin and the base of the caudal fin. Such a photophore is also included in the AC counts.

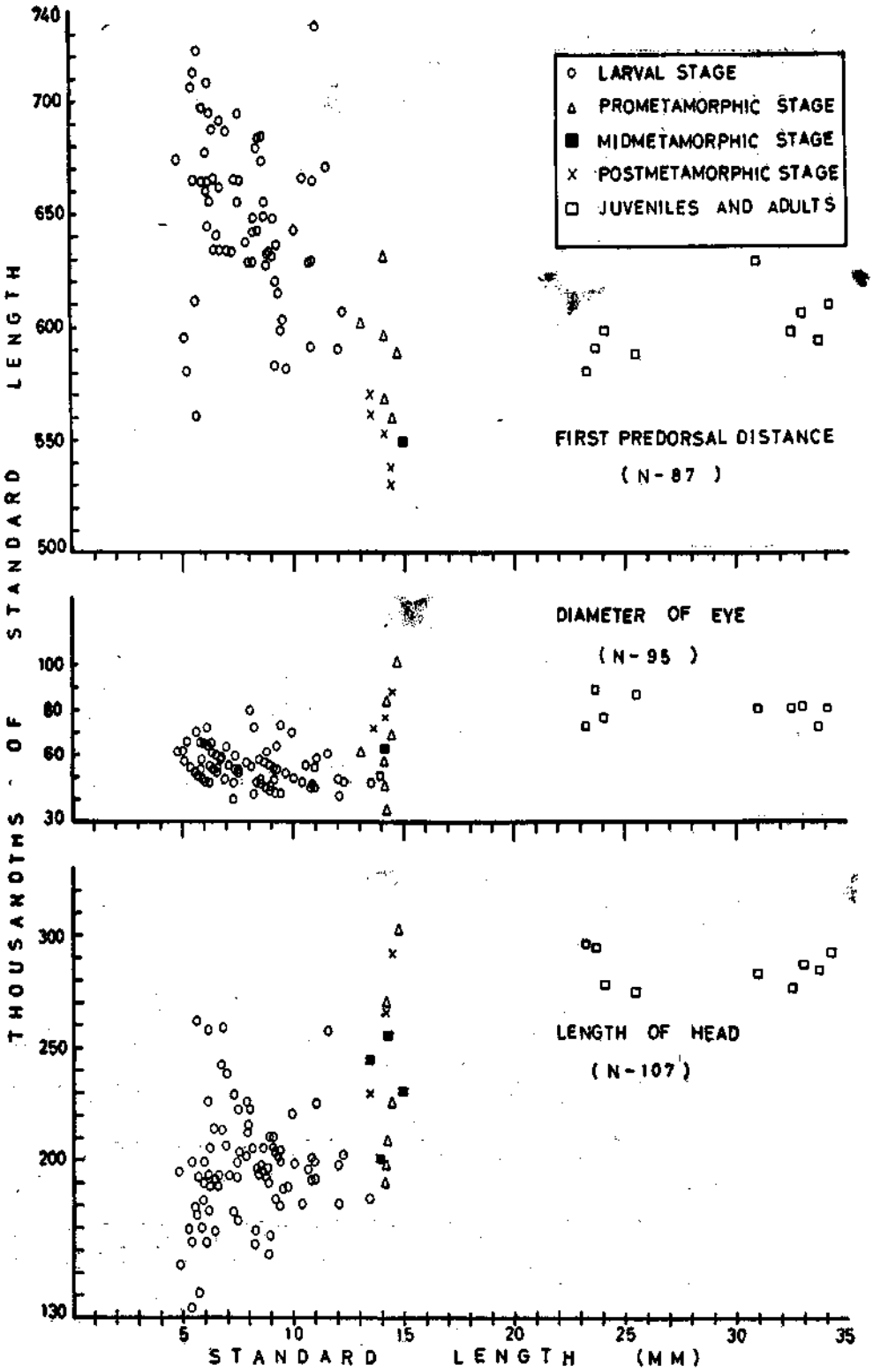

FIG. 2. *V. nimbaria* (Jordan and Williams). Changes in body proportion of three salient characters, namely Head, diameter of eye and first predorsal distance in relation to standard length for specimens from the Arabian Sea.

DESCRIPTIVE ACCOUNT OF THE SEQUENCE OF CHANGES OF CHARACTERS FROM LARVAL STAGE TO ADULT

In view of the marked changes between the larval stage and juveniles due to the three intervening metamorphosing stages and the considerable overlap in the lengths in the various stages it is felt desirable to base the descriptive account on the sequence of development of the various characters at the different stages rather than give descriptions of a few specimens. The sequence of development in the following characters are dealt with below :

1. Changes in body form from larvae to adult.
2. Changes in pigmentation during development.
3. Sequence of calcification (Available information regarding vertebrae gill rakers, teeth, branchiostegals, fin formation and fin rays).

I. CHANGES IN BODY FORM FROM LARVAE TO ADULT

Altogether 526 specimens were examined and detailed measurements were taken for 136 specimens including 9 juveniles and adults. In Table 2 the average measurements and counts for 0.5 mm length-groups of the larval and metamorphosing stages are indicated. Specimens damaged or not in good shape have not been measured.

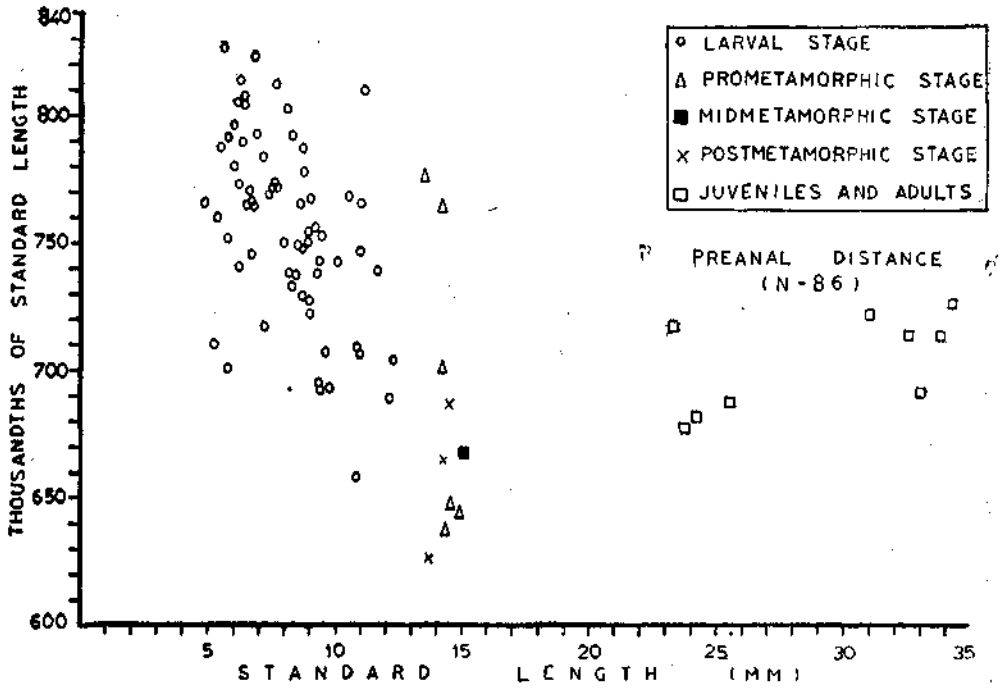

FIG. 3. *V. nimbaria* (Jordan and Williams). Change in preanal distance noticed during developmental stages.

The changes in body form as seen in four salient characters, namely first predorsal distance, diameter of eye, length of head, and preanal distance are graphically illustrated in Figures 2 and 3. From these figures the considerable overlap in the

size range of metamorphosing stages and in turn the relatively restricted length range within which these changes from the end of larval stage to juveniles take place is evident.

The measurements and percentages given below are based on material actually examined for each character.

1. *Head* (Fig. 2) : In larval stage from 4.3 (T.L.) to 13.9 mm. (S.L.) the head length varies from 13.4 to 26.2 per cent of standard length. In the metamorphosing stages (combined) from 12.0 to 15.0 mm. (S.L.), the head length ranges from 19.0 to 30.1 per cent, while juveniles and adults between 23.3 to 34.2 mm. (S.L.) show a range of 27.4 to 29.6 per cent. As may be seen from Fig. 2, there is hardly any increase in the length of the head in relation to standard length in the juveniles and adults. A wide range of variations in the length of the head is thus noticeable during larval and metamorphosing stages indicating also a progressive increase in the length of the head upto the postmetamorphic stage.

In the earliest larval stage (4.3 mm. T.L., Fig. 4), the head has a more or less truncate snout and the lower jaw is conspicuous and projects beyond. In larger specimens of different sizes of the larval stage (Figs. 5 and 6), the snout becomes more elongate, slightly depressed and blunt, but the lower jaw all through the larval stage conspicuously juts out giving a very characteristic profile for the head. During the postmetamorphic stage (Fig. 8b) the head profile assumes the general shape as seen in juveniles and adults.

2. *Eye* (Fig. 2) : The eyes appear slightly pedunculate in the early larval stage (Figs. 4 and 5), but by about 8.5 mm. (T.L.) they show some retraction tending to just bulge out of the lateral profile of the head (Fig. 6). This condition is seen even in more advanced larval stage, but in the prometamorphic stage the eyes are flush with the sides of the head (Fig. 7). The transition of the shape of the eye from the oblong to the rounded condition is a conspicuous feature noticeable between the prometamorphic and postmetamorphic stages.

As in the case of the length of head in relation to standard length, the diameter of the eye shows a wide range of variations, especially in the larval and metamorphosing stages. The diameter of the eye for the different stages are as follows : in the larval stage 4.9 to 13.6 mm. (S.L.) it is 4.0 to 8.0 per cent of standard length. In the metamorphosing stages, 13.1 to 14.8 mm. (S.L.) it is 3.4 to 10.0 per cent. For juveniles and adults 23.3 to 34.2 mm. (S.L.) it is 7.2 to 8.8 per cent.

3. *Depth of body :* In the larval stage for specimens 5.5 to 12.3 mm. (S.L.) the depth at pectoral origin varies from 4.5 to 7.2 per cent of standard length. In the prometamorphic stage, for specimens from 13.1 to 14.8 mm. (S.L.) it is 9.9 to 17.4 per cent. In the midmetamorphic stage for one specimen 15.0 mm. (S.L.) it is 10.0 per cent. In the postmetamorphic stage for specimens 13.7 to 14.5 mm. it is 14.4 to 16.3 per cent while in juveniles and adults from 23.3 to 34.2 mm. (S.L.) it is 16.4 to 19.2 per cent.

Thus in *V. nimbaria* there is a conspicuous increase in the greatest depth of the body on transition from larval through metamorphosing stages. A similar phenomenon has also been observed for *V. lucetia* by Ahlstrom and Counts (1958).

4. *Peritoneal lining :* Increase in the pigmentation of the peritoneal lining of the abdomen is noticeable during the metamorphosing stages, particularly during the postmetamorphic stage.

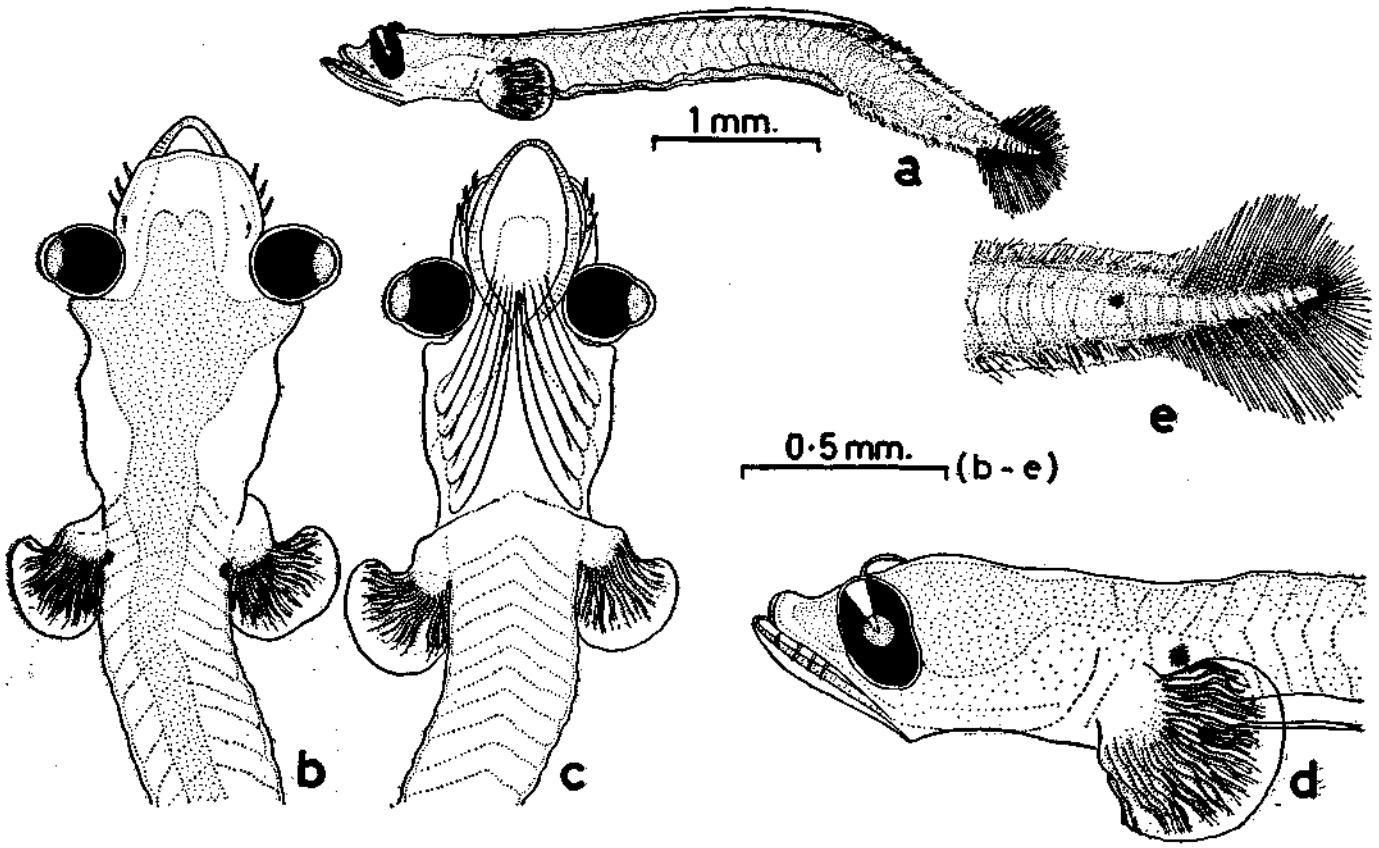

FIG. 4. *V. nimbaria* (Jordan and Williams). Larval Stage. *a-e* Larva 4.3 mm. (T.L.) from R.V. *VARUNA* Station 1415. *a*. Lateral view ; *b*. dorsal view of head ; *c*. ventral view of head ; *d*. lateral view of head ; *e*. caudal region showing larval fin and disposition of chromatophores. Branchiostegals not fully formed.

5. *First predorsal distance :* (Fig. 2). In the larval stage for specimens 4.9 to 12.0 mm. (S.L.) the first predorsal distance is 56.0 to 73.3 per cent of standard length. It is 56.0 to 63.0 per cent in the prometamorphic stage for specimens 13.1 to 14.8 mm. (S.L.). In the midmetamorphic stage for a specimen 15.0 mm. (S.L.) it is 54.8 per cent, while in the postmetamorphic stage for specimens 13.7 to 14.5 mm. (S.L.) it is 53.0 to 56.1 per cent. In juveniles and adults, 23.3 to 34.2 mm. the predorsal distance is 58.0 to 62.7 per cent. Thus it would appear that from larvae to adults there is a relative decrease in the first predorsal distance.

6. *Preanal distance :* (Fig. 3). In the larval stage for specimens 4.9 to 12.0 mm. it is 66.0 to 81.0 per cent of standard length. During prometamorphic stage in specimens 13.1 to 14.8 mm. the preanal distance is 63.5 to 76.3 per cent. In a specimen 15.0 mm. in midmetamorphic stage it is 67.3 per cent. In the postmetamorphic stage of specimens 13.7 to 14.5 mm. it is 62.6 to 68.6 per cent. In juveniles and adults 23.3 to 34.2 mm. it is 67.3 to 72.5 per cent. On the whole, as in the case of first predorsal distance there appears to be a slight reduction in the preanal length during development.

II. Changes in Pigmentation during Development

1. *Larval Stage :* In the smallest specimen available to us (4.3 mm. : Fig. 4 a-e) a conspicuous chromatophore is present below the urostyle at the base of the differentiating caudal fin and a similar chromatophore on the side of the caudal peduncle on the ninth post-anal myotome. Anteriorly just above and behind the base of the pectoral (mid-laterally) a well developed chromatophore is present. Pigmentation is not evident on other parts of the body.

In a 5.3 mm. (T.L.) larva (not figured) in addition to the chromatophores seen in the 4.3 mm. larva (T.L.), a small pigment spot is present just below the tip of the upturned urostyle.

Table 3

Location of pigment areas in larvae of V. nimbaria

Length (mm.)	Mid-lateral (above pectoral)	Pectoral	Vent	Anal fin base	Pre-caudal	Caudal	Base of Caudal	
							Upper	Lower
4.3 (TL)	×	—	—	—	×	×	—	—
5.7 (TL)	×	—	—	—	×	×	—	—
5.9 (TL)	×	—	×	—	×	×	×	—
6.1 (TL)	×	—	×	×1*	×	×	×	—
7.5 (TL)	×	—	×	×2	×	×	×	—
8.2 (SL)	×	—	×	×2	×	×	×	—
8.5 (SL)	×	—	×	×1	×	×	×	×
8.9 (SL)	×	—	×	×3	×	×	×	×
9.8 (SL)	×	×	×	×2	—	×	×	×
10.0 (SL)	×	×	—	×3	×	×	×	×
10.5 (SL)	—	×	—	×4	—	×	×	×
12.3 (SL)	—	×	—	×4	—	×	×	×
14.0 (SL)	—	×	—	×3	—	×	×	×

(An × denotes presence of pigment spot or chromatophore. TL=Total length. SL=Standard length. An (*) indicates number of chromatophores above anal base.)

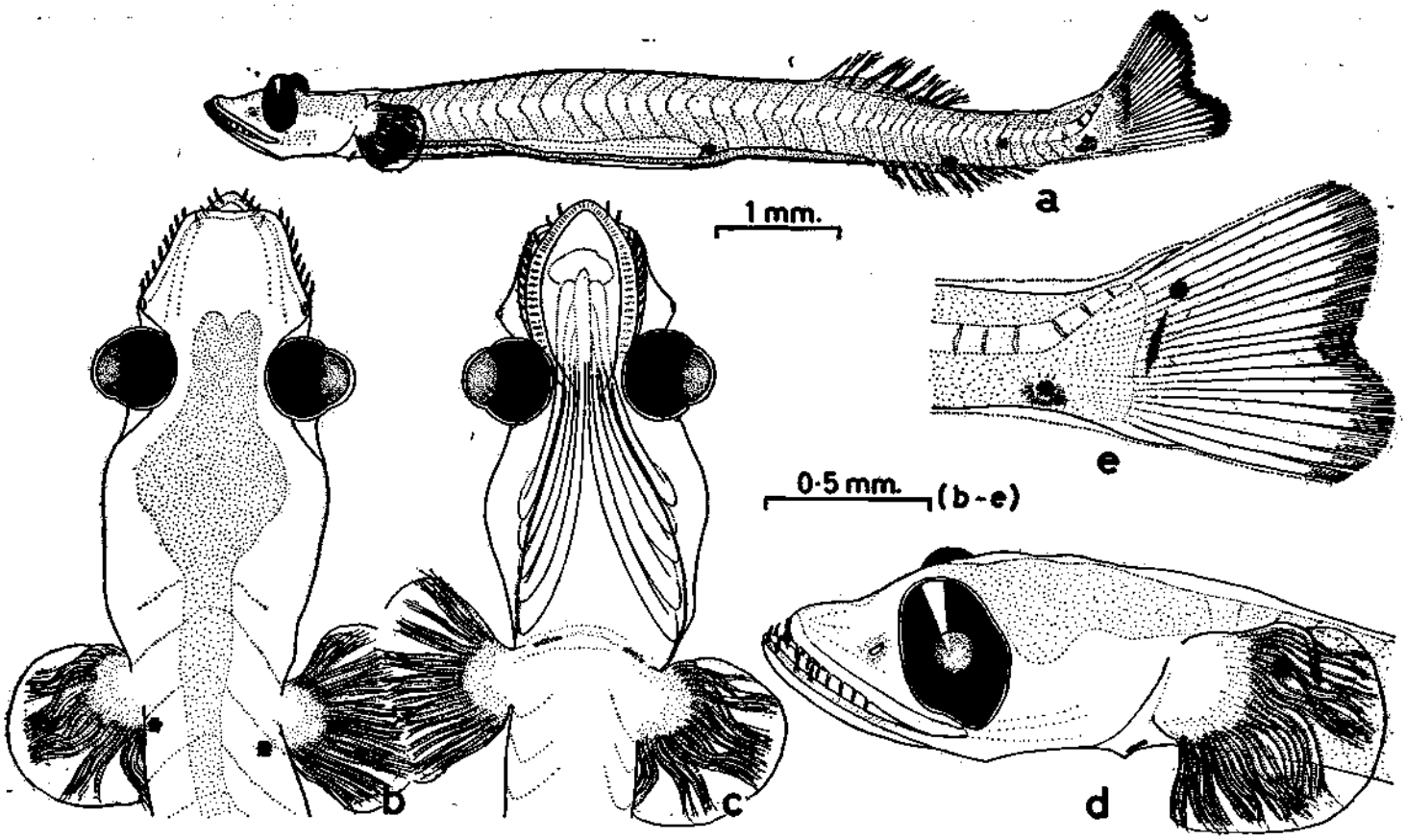

FIG. 5. *V. nimbaria* (Jordan and Williams). Larval Stage. *a-e* Larva 8.5 mm. (T.L.) from R.V. *VARUNA* Station 1391. *a*. Lateral view ; *b* and *c*. dorsal and ventral views of head and anterior part of body ; *d*. head slightly tilted showing disposition of eye and teeth ; *e* Caudal region showing disposition of chromatophores (Chromatophore on body overlapped by larval pectoral also indicated in *a* & *d* ; branchiostegals not fully formed).

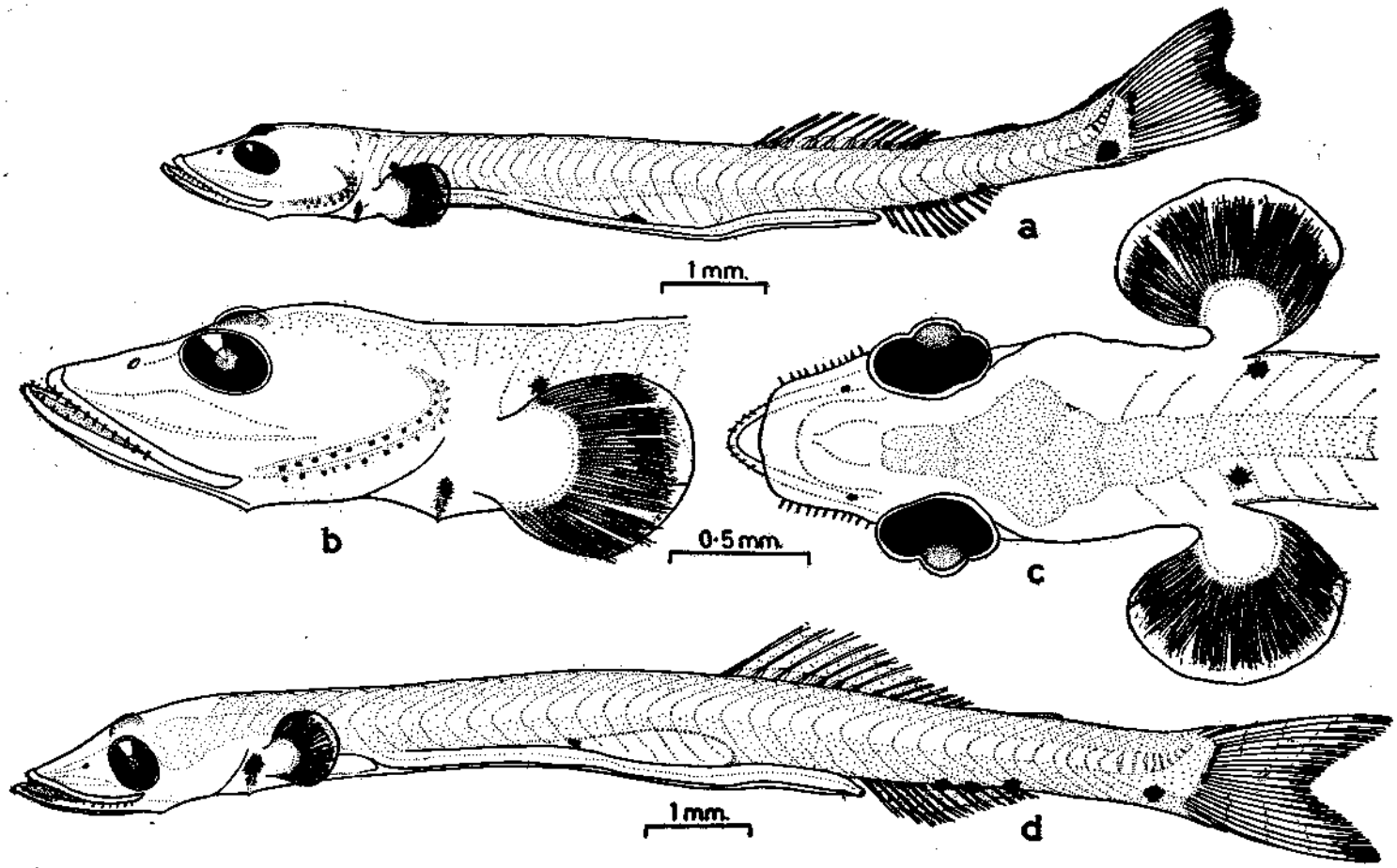

FIG. 6. *V. nimbaria* (Jordan and Williams). Larval Stage. *a-d* Larvæ 11.0 and 13.5 mm. (T.L.) from R.V. *VARUNA* stations 1391 and 1437. *a* to *c*. Larva 11.0 mm. from Stn. 1391 ; *d*. Larva 13·5 mm. from Stn. 1437.

In a 8.5 mm. (T.L. ; 7.5 mm. S.L.) (Fig. 5 a-e) larva in which the caudal fin has become slightly emarginate, the pigmentation close to the base of the caudal fin is in the form of a short oblique bar topped by a distinct chromatophore. The large chromatophore at the posterior lower corner of the caudal peduncle is conspicuous and a similar chromatophore is present above the base of the anal fin. Midlaterally one chromatophore is present on the 12th postanal myotome. A characteristic dusky streak is present close to the clavicle well below base of pectoral. The chromatophore below base of pectoral on body is conspicuous and clearly seen through the larval pectoral fin.

In a 9.0 mm. (S.L. ; T.L. 10.0 mm ; not figured) larva, three chromatophores are present above the base of the anal fin in addition to the conspicuous one on the posterior lower corner of the base of the caudal peduncle. The pigment streak at the base of the caudal fin is broken into two above which are present two small chromatophores. The midlateral chromatophore above the base of the pectoral persists and also the streak close to the clavicle. In another larva of 10.5 mm. (T.L.) 4 chromatophores are present at the base of the anal fin.

In a larva 9.5 mm. (S.L. ; T.L. 11.0 mm. ; Fig. 6 a-c) the pigmentation is as follows : The pigment streak close to the clavicle is very distinct and so also the midlateral chromatophore behind and above the base of the pectoral on the body. Three chromatophores are present at the base of the anal fin. The conspicuous chromatophore at the lower posterior corner of the caudal peduncle persists. The pigment streak at the base of the caudal is broken into four. The midlateral chromatophore on the caudal peduncle seen in early larvae is wanting and is not present in subsequent stages as well.

Just prior to the prometamorphic stage in the most advanced larval stage in a larva measuring 13.5 mm. (T.L.) the general pattern of pigmentation remains the same except that the chromatophore just above and behind the base of the pectoral on the body is wanting (Fig. 6 d).

2. *Prometamorphic Stage :* In a specimen 14.0 mm. (S.L. ; 16.1 T.L. ; Fig. 7 a-c) the conspicuous and branched chromatophores at the posterior lower end of the caudal peduncle and the pigment streak at the base of the caudal are present. Two diffuse and dusky chromatophores are present above the base of the anal fin and a narrow dark streak close to the clavicle. Photophores are opaque having not developed any pigmentation. In a smaller prometamorphic stage larva measuring 12.2 mm. (S.L. ; 14.1 mm. T.L. ; Fig. 7 d) there is no change in the pattern of pigmentation.

3. *Midmetamorphic Stage :* In a specimen 15.5 mm.(S.L. ; T.L. 17.3 mm.; Fig. 8 a) the chromatophore at the lower posterior end of the caudal peduncle and the single chromatophore at anal base still persist, but are diffuse. On the sides of the abdomen faint brownish chromatophores are developed and similar ones appear above the occipital region. The peritoneal lining turns black and this is evident from the dark colour seen along part of the abdomen. Remnants of the pigment streak close to the clavicle is still present. Photophores show evidence of slight pigmentation.

4. *Postmetamorphic Stage :* In a specimen of identical length as the previous stage (15.5 mm. S.L. ; Fig. 8 b), much of the larval pigmentation is lost. A diffuse patch each at the lower posterior end of the caudal peduncle and at the baseof the

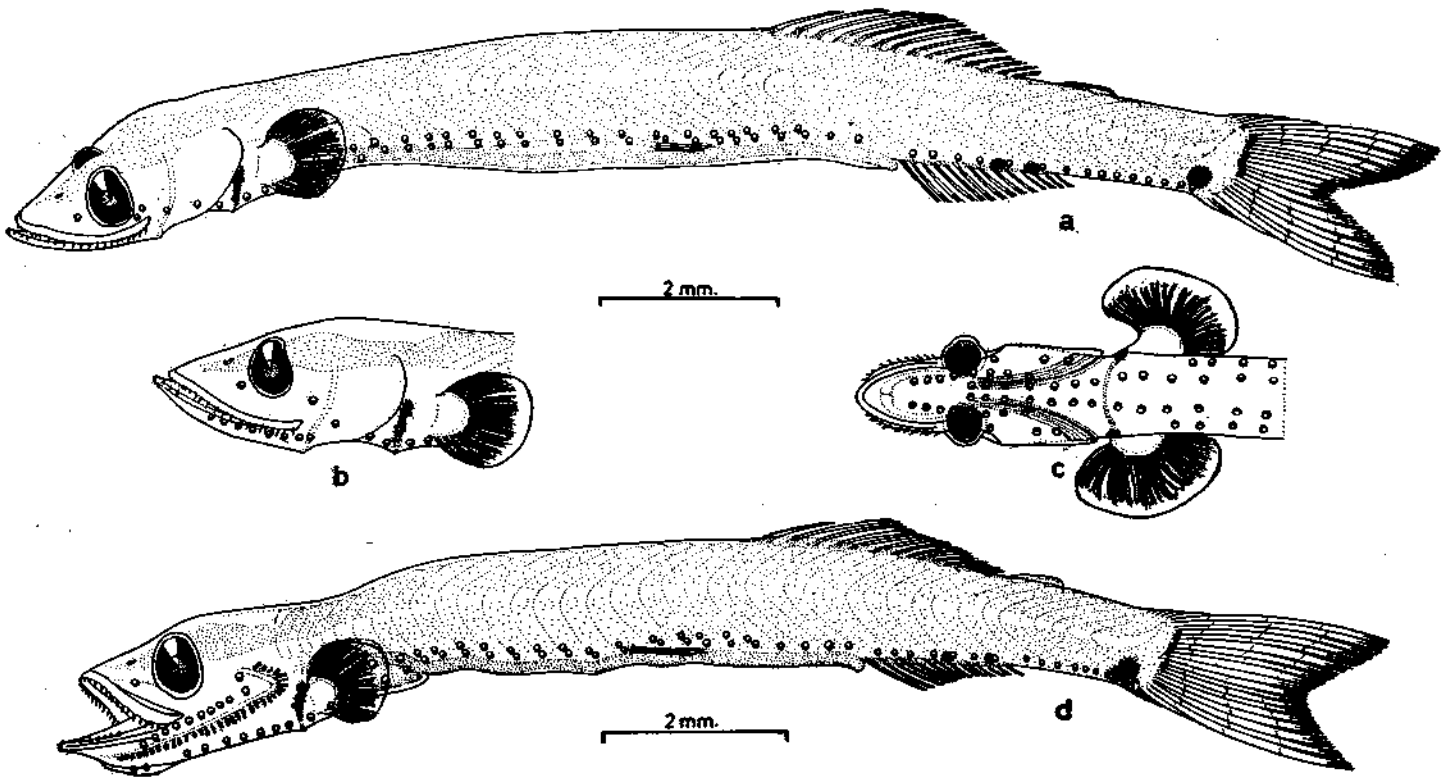

FIG. 7. *V. nimbaria* (Jordan and Williams). *a-d.* Prometamorphic Stage. *a-c.* larva 16.18 mm. (T.L.) from R.V. *VARUNA* Station 2034 ; *d.* larva 14.1 mm. (T.L.) from Station 1181. (Full complement of branchiostegals not shown in fig. *c.*).

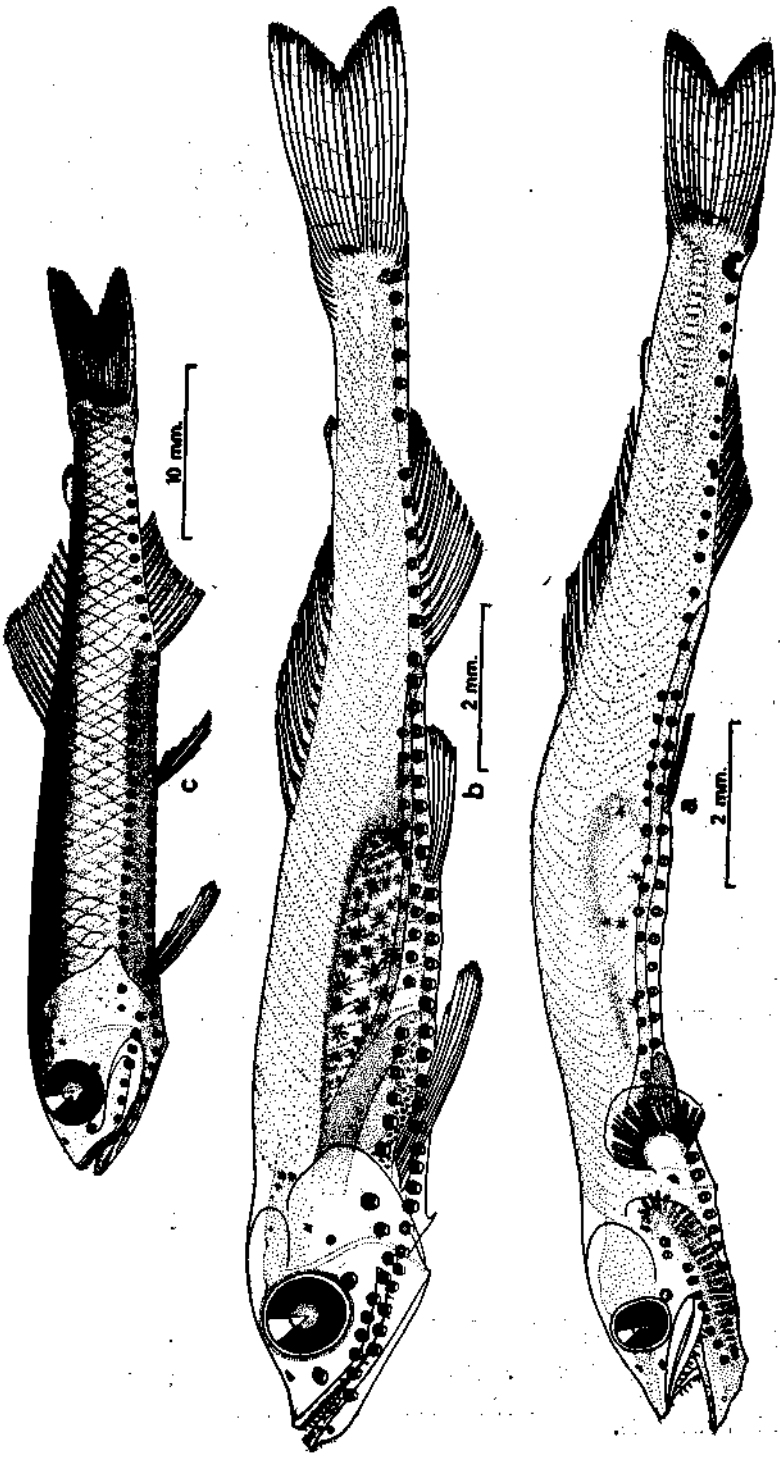

FIG. 8. *V. nimbaria* (Jordan and Williams). *a*. Midmetamorphic stage of specimen 17.3 mm. (T.L.) from R.V. *VARUNA* Station 2075 ; *b*. Postmetamorphic Stage from same station. Length 17.3 mm. (T.L.) ; *c*. Adult 52.5 mm. (T.L.).

caudal only remain. The brownish chromatophores on the abdomen and the nape are more developed. The cup-shaped portion of the photophores are dark with whitish lens as in adults.

5. *Juveniles and adults :* The upper part of the body and head are dusky. The abdomen, especially between the two rows of photophores is dusky upto the vent. Similar pigment spots are present above the base of the caudal fin. The scales are deciduous and scale pockets are discernible on account of the fine rows of pigment spots. An adult 52.5 mm. (T.L.) is shown in Fig. 8 c.

The location of pigment spots in the larval stages of *V. nimbaria* is shown in Table-3.

III. Sequence of Calcification

In order to follow the sequence of calcification 37 specimens (Table 4) belonging to the larval stages have been cleared and stained in Alizarine Red. Here the changes

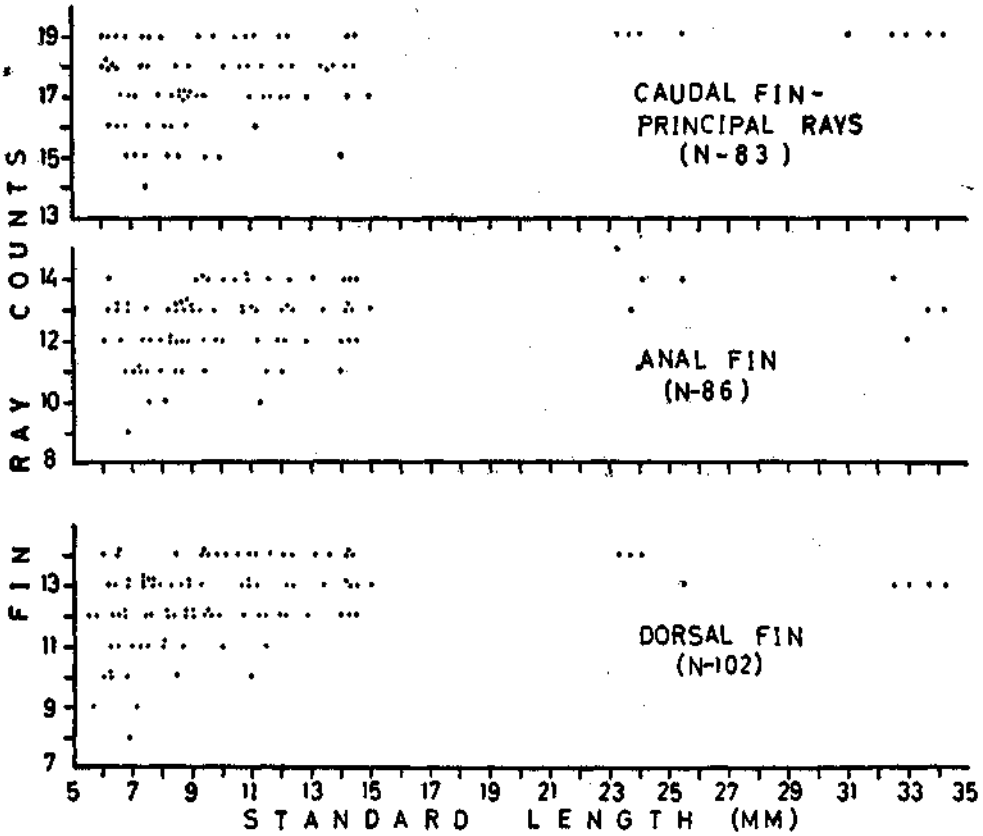

Fig. 9. Frequency of occurrence of dorsal, anal and caudal fin rays in relation to developmental stages in *V. nimbaria*.

seen in the paired and unpaired fins, gill rakers, teeth, etc., are discussed. Observations made on unstained specimens are also included.

TABLE 4

Meristic counts in Alizarine stained specimens of larval stages and juveniles of Vinciguerria nimbaria

S.L.* (mm.)	D_1	A	C	P_1	Teeth			Verte-brae	Gill rakers	Myo-tomes	Dev. stage
					PMX	MX	MD				
6.0	8	L**	iii, 17, ii	L	Nil	6 : 5	1 : 1	—	Nil	27+13	LS
6.2	L	L	iv, 18, ii	L	Nil	7 : 7	3 : 2	—	Nil+6	27+12	LS
6.5	11	L	ii, 19, iii	L	Nil	—	3: 3	—	—	—	LS
6.6	12	L	ii, 17, iii	L	Nil	8 : 8	4 : 5	—	Nil+9	27+13	LS
7.0	12	12	i, 18, ii	L	Nil	7 : 8	4 : 4	—	Nil+7	—	LS
7.0	11	L	i, 18, iii	L	Nil	8 : 8	4 : 4	—	—	—	LS
7.0	11	L	—	L	—	—	4 : 4	—	Nil+7	—	LS
7.2	13	11	i, 18, ii	L	Nil	8 : 8	4 : 4	—	Nil+7	26+14	LS
7.3	12	L	ii, 18, iii	L	Nil	8 : 8	3 : 3	—	Nil+8	—	LS
7.4	11	L	iii, 19, ii	L	Nil	—	5 : 5	—	Nil+8	27+12	LS
7.4	11	12	ii, 19, ii	L	—	10 : 10	5 : 5	—	Nil+9	27+13	LS
7.5	12	13	ii, 19, ii	L	Nil	9 : 9	4 : 4	—	Nil+9	—	LS
7.6	D	PL	iii, 18, ii	L	Nil	9 : 9	4 : 5	—	Nil+9	—	LS
8.0	—	12	ii, 18, i	L	Nil	—	4 : 4	—	Nil+8	—	LS
8.0	12	13	iii, 19, ii	L	Nil	9 : 9	5 : 4	—	Nil+9	—	LS
8.0	12	13	ii, 19, iii	L	Nil	10 : 10	5 : 4	—	Nil+10	—	LS
8.2	12	11	i, 19, ii	L	Nil	9 : 8	4 : 4	—	Nil+9	—	LS
8.5	11	11	iii, 17, ii	L	1:0	10 : 10	6 : 6	—	Nil+9	27+13	LS
9.0	11	12	iii, 19, ii	L	1 : 1	12 : 12	6 : 7	—	Nil+9	—	LS
9.0	12	13	ii, 19, i	L	1 : 1	12 : 12	6 : 6	—	Nil+11	—	LS
9.0	13	12	iii, 19, iii	L	Nil	12 : 12	6 : 6	—	Nil+12	—	LS
9.4	12	12	iii, 19, ii	L	Nil	8 : 9	4 : 4	—	Nil+8	27+12	LS
9.6	13	13	i, 19, iii	L	Nil	10 : 10	4 : 4	—	Nil+10	26+14	LS
9.6	12	12	iv, 19, ii	L	Nil	11 : 12	6 : 6	—	1+11	—	LS
9.8	14	14	iii, 19, ii	L	Nil	10 : 11	5 : 4	—	Nil+10	—	LS
10.2	12	12	iii, 19, iii	L	—	12 : 12	6 : 5	—	Nil+11	—	LS
10.5	14	14	vi, 19, iv	L	2 : 2	11 : 12	5 : 6	—	Nil+14	—	LS
10.8	13	13	iv, 19, iii	L	1 : 1	12 : 11	6 : 6	—	Nil+11	27+13	LS
11.4	D	D	iv, 19, iii	L	—	11 : 11	—	—	—	27+14	LS
12.0	14	14	iii, 19, ii	L	2 : 2	11 : 11	6 : 6	—	Nil+11	27+13	LS
12.8	14	14	viii, 19, iv	L	1 : 1	13 : 12	4 : 4	—	4+14	26+16	MDS
13.4	13	14	ix, 19, iv	10	1 : 1	12 : 14	6 : 5	—	4+16	25+15	POS
14.1	14	14	viii, 19, v	10	3 : 4	16 : 13	5 : -	—	4+14	27+13	POS
15.1	13	14	ix, 19, iv	—	4 : 3	15 : 16	—	40+1@	3+16	26+15	POS
23.3	14	15	ix, 19, iv	10	11 : 15	36 : 35	32 : 33	38+1	7+17	—	J
24.1	14	14	ix, 19, iv	10	13 : 15	40 : 39	25 : 25	41+1	7+17	—	J
25.5	13	14	x, 19, iv	10	—	—	—	38+1	7+17	—	J

In the above table, the countable preanal and postanal myotomes are indicated separately. (*) Total length is taken for specimens upto a length of 7.4 mm. after which the caudal fin is well differentiated to help take the standard length measurement. (**) Fin ray counts are not indicated in larval fins in which only a few rays are formed (PL).

(A = No. of anal fin rays ; C=No. of primary and secondary caudal fin rays ; D=Damaged ; D_1=No. of dorsal fin rays ; J=Juveniles ; L=Larval fin ; LS=Larval Stage ; MD=Mandibular teeth ; MDS=Midmetamorphic stage ; MX=Maxillary teeth ; P_1=No. of pectoral fin rays ; PMX=Premaxillary teeth ; POS=Postmetamorphic stage).

1. *Dorsal fin :* (Fig. 9). The first dorsal fin is larval in 4.3 mm. (T.L.) specimen and appears to be partly larval upto about 6.0 mm. T.L. after which 8 to 14

rays develop during the larval stage. The normal complement of first dorsal fin rays in juveniles and adults is 13 or 14 rays.

2. *Anal fin :* (Fig. 9). The development of the anal fin when compared to the first dorsal appears to be more delayed and larvae 7.6 mm. (T.L.) have been observed to have partly larval fin although between 7.0 and 7.5 mm. (T.L.) some larvae show 11 to 13 developing rays. The counts observed for juveniles and adults is 12 to 15 rays and larvae upto 12 mm. (S.L. ; Fig. 9) have 9 to 14 rays.

3. *Caudal fin :* (Fig. 9). The principal caudal rays in juveniles and adult are constant being 19 rays. However, in the earliest larva (4.3 mm. T.L.) the caudal is larval and by 5.7 mm. (T.L.) 14 branched rays are seen. In the earliest larval stage the larval caudal has a rounded margin and it becomes slightly emarginate by about 8.5 mm. (T.L.) and during the metamorphosing stages progressively more forked ; this condition becoming well developed in juveniles and adults. In the larval and early metamorphic stages the principal caudal rays may vary from 14 to 19. The secondary caudal rays are developed more in numbers along the upper caudal base than the lower caudal base and the earliest indications of these rays are seen in specimens about 6.0 mm. (T.L.). Although in the larval stage as may be seen from Tables 2 and 4 the frequency of the number of secondary rays may be variable, the general trend is for the occurrence of more secondary rays at the upper base of the caudal fin. However, during the late larval stage (in specimens over 10.5 mm. S.L.) and in metamorphosing stages and juveniles the differences in number between the upper and lower secondary caudal rays are marked (Fig. 10 e), the former numbering upto 10 rays, while the latter shows a maximum count of 5 rays.

4. *Pectoral fins :* The larval pectoral fin is present even in the smallest larva measuring 4.3 mm. in the sample. The pectoral fin is larval throughout the larval stage (Tables 2 and 4) and so also during part of the metamorphosing stages. The transition from larval pectoral to those with well developed rays takes place at end of midmetamorphic stage. This also coincides with the photophores becoming darker as in juveniles and adults. An Alizarine stained specimen (15.5 mm. S.L.) of the postmetamorphic stage (not figured) still retains partly larval pectorals, while another specimen of the same stage and of identical measurements shows 8 well developed rays (Fig. 8 b). Two other specimens in post metamorphic stage measuring 13.4 and 14.1 mm. (S.L.) show 10 rays in each pectoral. Pectoral rays appear to vary between 8 and 10 rays in juveniles and adults and the normal complement in adults appear to be 9 or 10 rays.

5. *Pelvic fins :* The earliest indications of pelvic fins are seen in the late larval stage in specimens measuring about 13.5 mm. (T.L.) (Fig. 6 d) and they are present as rudimentary buds on the 10th preanal myotome counted forwards from vent. Only during the prometamorphic stage the differentiation of the rays are evident. The pelvic fin ray count for the adult is 7 rays.

6. *Gill rakers :* (Fig. 10 a). The gill raker counts from 37 Alizarine stained specimens are presented in Table 4. It was difficult to make accurate counts on unstained material of the larval stages, but this was not so for juveniles and adults. The full complement of gill rakers in the adult was found to be 6 or 7 (mode 7) on the upper limb of the outer arch and 15 to 17 (mode 16) on the lower limb (Fig. 11).

During the larval stages gill rakers on the outer gill arch as a rule do not develop on the upper limb, but in two specimens (9.0 and 9.6 mm. S.L.) one bud each

is present just above the angle of the outermost gill arch. Gill rakers on the lower limb are absent in a larva 6.0 mm. (T.L.). The earliest indications are 6 buds on the lower limb in a larva 6.2 mm. (T.L.). In the larval stage between 6.2 mm. and 12 mm. the number of gill rakers including rudimentary buds on the lower limb of the outer gill arch increases more or less with size from 6 to 14.

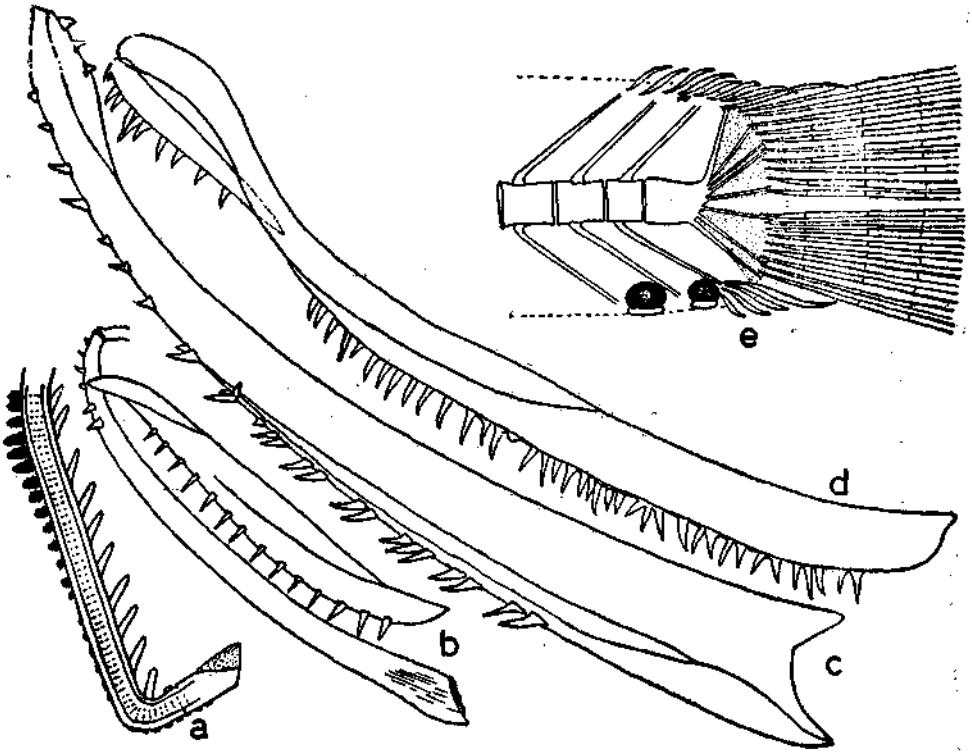

FIG. 10. *V. nimbaria* (Jordan and Williams). *a*. Outer gill arch in larva 9.6 mm. (S.L.) showing rudimentary gill rakers ; *b*. Maxilla and mandible of larva 12.0 mm. (T.L.) showing disposition of teeth ; *c*. Mandible of juvenile 29.5 mm. (T.L.) with teeth ; *d*. Premaxilla and maxilla of young adult 32.0 mm. (T.L.) showing teeth ; and *e*. Caudal skeletal elements of specimen 29.5 mm. (T.L.).

During the metamorphosing stages, 3 or 4 gill rakers are present on the upper limb and 14 to 16 rakers on the lower limb. The 6 or 7 plus 15 to 17 (modal formula 7+16) is characteristic of *V. nimbaria*, while in the related species *V. lucetia* the counts are 8 to 10 plus 18 to 23 rakers.

7. *Development of Teeth :* As in *V. lucetia* the maxillaries appear to be the first jaw bones to get ossified and larval teeth are formed on these earlier than on the other elements. The first appearance and occurrence of teeth on premaxillaries, maxillaries and mandibulars are indicated in Table 4 and a few conditions seen in development are shown in Fig. 10.

During the larval stage, the earliest occurrence of teeth on premaxillaries was seen in larva 8.5 mm. (T.L.) although some specimens upto about 10 mm. (S.L., 12 mm. T.L.) did not bear teeth on premaxillaries.

In a 6.0 mm. (T.L.) larva 6 and 5 teeth were present on either maxillaries and there is a progressive increase in their numbers with growth. During the metamorphosing stages this varies from 12 to 15 on each maxillary, but in juveniles it is generally over 35 in number.

Unlike the maxillaries, the mandibular teeth are much fewer at first appearance and during the larval and metamorphosing stages they are present towards the symphysis of the mandible (Fig. 10 b). The number of teeth progressively increases during the larval and metamorphosing stages, but their numbers do not vary much during these growth stages, there being generally 3 to 7 teeth on either mandible. However, there is a marked increase in the number of mandibular teeth in the early juveniles (e.g. 29.5 mm. T.L., Fig. 10 c), their number being 25 or more. In addition about three teeth are borne in a second row on either side of mandibular symphysis.

In a juvenile of 32.0 mm. (T.L. ; Fig. 10, d) on the maxillary the larger and stouter teeth of the inner and outer series are closely juxtaposed (especially on the posterior half of the maxillary) the teeth diverging from base. This condition is more pronounced in adults where the maxillary teeth when viewed from outside appear ' bifid '.

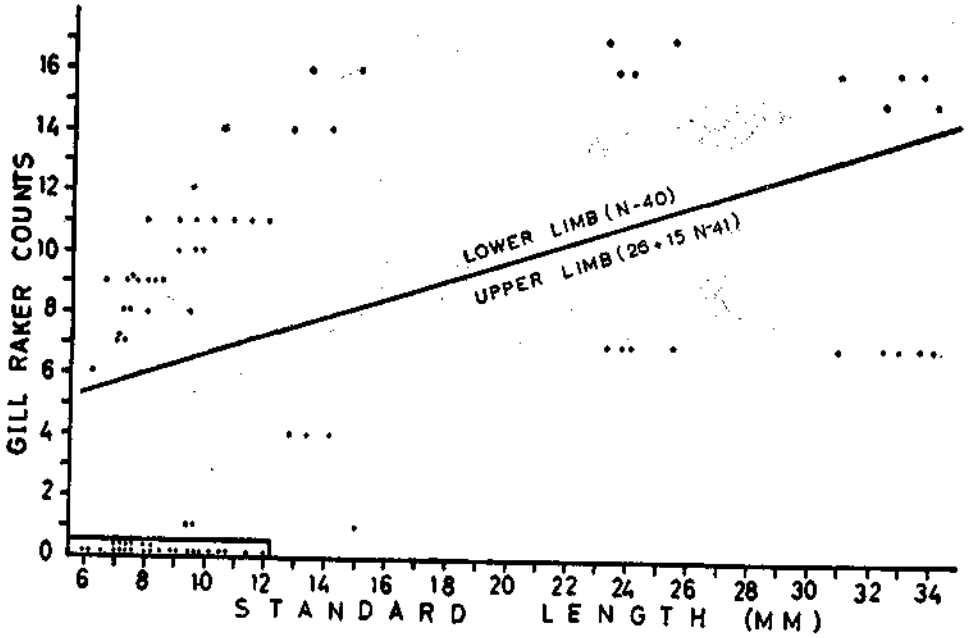

FIG. 11. *V. nimbaria* (Jordan and Williams). Frequency of occurrence of gill rakers in the larval stages and the adult.

On the premaxillaries the teeth are uniserially arranged and are fewer in number than on the maxillaries. The teeth are generally long and slightly curved inwards. In the adult mandible the teeth on the posterior half are exactly not uniserially arranged. However, the mandibles bear numerically more teeth, larger ones almost alternating with one or two shorter teeth.

In a specimen 23.3 mm. (S.L., 29.6 mm. T.L.) the vomer has two pairs of conical slightly recurved teeth. The palatines of each side has four uniserially arranged conical teeth, the posteriormost of the series being the largest. In this specimen,

the premaxillary teeth are uniserially arranged with four large teeth intervened by a number of smaller teeth, the total number on one side being 11 and the other 15.

8. *Branchiostegals :* Branchiostegals are formed during the late larval stage, though developing ones are seen in earlier larvae. The full complement of branchiostegals in juveniles and adult is 12. In an early juvenile 23.3 mm. (S.L.) the branchiostegals are short and the posteriormost four do not have photophores situated between them. The anterior eight branchiostegals alternate with eight branchiostegal photophores.

9. *Vertebrae and Myotomes :* The total number of vertebrae in juveniles and adults are found to vary from 39 to 42 (Table 5).

Myotome counts are not found to vary much. The preanal myotome in the larval stage are found to number 25 to 27. The lesser count of 25 preanal myotomes may be partly due to the difficulty in counting the anteriormost myotomes. In early larval stage, all postanal myotomes are not clear. The countable numbers are indicated in Table 4. However, later larvae and metamorphosing stages show either 15 or 16 postanal myotomes.

IV. Photophore Development in *V. nimbaria*

In the well developed condition each photophore has an inverted urn-shape, black at base and with a whitish area (grey silver lens in life) directed downwards. The photophore arrangement is very characteristic for the genus *Vinciguerria* by which it can be easily distinguished from other gonostomatid fishes. Within the genus *Vinciguerria* the photophore arrangement is slightly different for the different species, but the typical arrangement for *V. nimbaria* is shown in Fig. 1.

TABLE 5

Variations in the number of body photophores in specimens of Vinciguerria nimbaria *from the Arabian Sea and the Eastern Pacific*

Number of Photophores	ARABIAN SEA					EASTERN PACIFIC				
	Lateral row		Ventral row		AC group	Lateral row		Ventral row		AC group
	OV group	VA group	IV group	VA group		OV group	VA group	IV group	VA group	
8-8	—	—	—	1	—	—	—	—	—	—
9-9	—	1	—	6	—	—	—	—	—	—
9-10 } 10-9 }	—	2	—	1	—	—	—	—	2	—
10-10	—	4	—	1	—	—	—	—	2	—
10-11 } 11-10 }	—	1	—	—	—	—	2	—	—	—
11-11	1	1	—	—	—	—	2	—	—	—
11-12	1	—	—	—	—	—	—	—	—	—
12-12	7	—	—	—	3	—	—	—	—	—
13-12	—	—	—	—	1	—	—	—	—	—
13-13	—	—	—	—	3	4	—	—	—	2
14-12	—	—	—	—	—	—	—	—	—	1
14-13	—	—	—	—	2	—	—	—	—	1
15-15	—	—	8	—	—	—	—	—	—	—
16-16	—	—	1	—	—	—	—	4	—	—

TABLE 6

Asymmetry in photophore pairing in various photophore groups in juveniles and adults of Vinciguerria nimbaria *from the Arabian Sea (A), and the Eastern Pacific (B)*

Photophore group	Frequency of specimens with photophore numbers				Percentage of specimens with asymmetrical pairing of photophores	
	Same on two sides of body		Different on two sides of body			
	A	B	A	B	A	B
SO	9	4	—	—	—	—
ORB	9	4	—	—	—	—
OP	9	4	—	—	—	—
DR	9	4	—	—	—	—
IS	8	4	1	—	11.1	—
OV	8	4	1	—	11.1	—
LVA	6	2	3	2	33.3	50
IV	9	4	—	—	—	—
VVA	8	2	1	2	11.1	50
AC	6	2	2	2	33.3	50

TABLE 7

Total number of photophores in Juveniles and adults of V. nimbaria *from the Arabian Sea and the Eastern Pacific*

Standard length (mm.)	Arabian Sea		Eastern Pacific (After Ahlstrom & Counts, 1958)	
	Right side	Left side	Right side	Left side
23.3	82	82	—	—
23.7	78	78	—	—
24.1	82	80	84	84
24.5	—	—	83	84
25.5	80	79	—	—
30.0	—	—	84	84
32.5	78	79	—	—
33.0	79	79	—	—
33.7	78	78	—	—
34.2	79	81	—	—
48.0	80	80	—	—
48.0	—	—	83	83

Most of the photophore groups are formed during the prometamorphic stage when they appear as round opaque discs. We have not been able to see the symphysial pair of photophores in the prometamorphic stage. During the mid and postmetamorphic stages the base of the photophores turns dusky to black, but the whitish downwardly directed area (lens) is conspicuous. The symphysial pair of photophores are present in these stages. A few late forming photophores are seen to appear during the juvenile to adult transition, especially in the lateral VA Group (2 or 3) and AC Group (1). The late forming photophores of the lateral VA Group develop above the posterior VA Group.

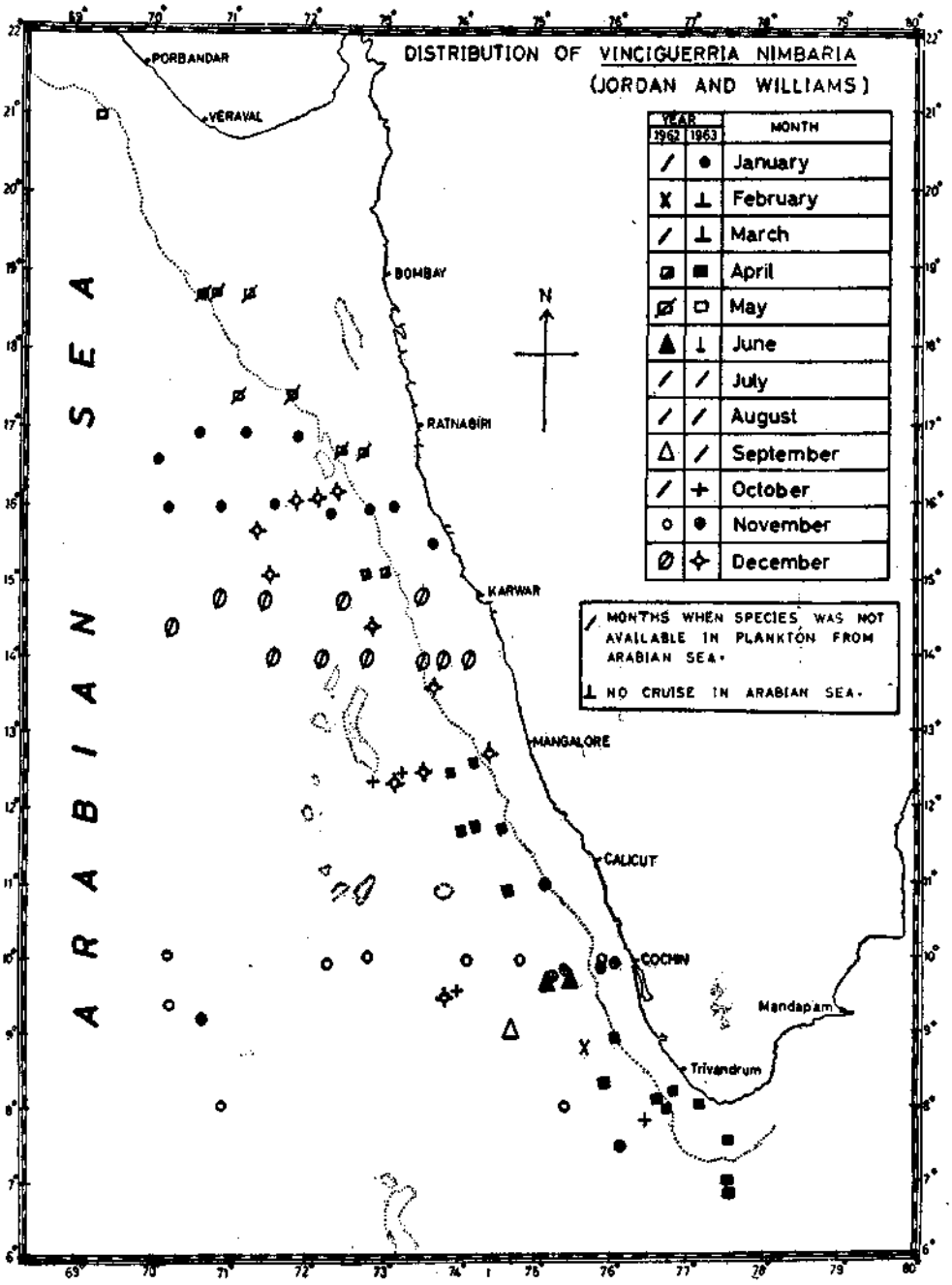

FIG. 12. Map showing the occurrence of *V. nimbaria* off the west coast of India and the Laccadive Sea for the monthly cruises of 1962-1963.

The frequency of occurrence of the various groups of photophores in juveniles and adults are indicated in Tables 6 to 8. A slight difference in the modal formulae of photophores between *V. nimbaria* and *V. lucetia* (the latter as given by Ahlstrom and Counts, 1958) is evident. In *V. nimbaria* itself slight difference is noticeable between material from the Arabian Sea and the Eastern Pacific (Tables 5 to 7). In the fewer number of photophores in the OV Group the specimens from the Arabian Sea shows affinities to *V. lucetia*, but as already mentioned their gill raker counts, ventral IV Photophore counts and anal fin ray counts are as for *V. nimbaria*. The frequency of occurrence of photophores in our specimens are based on only juveniles and adults, while the wide range of 84 to 87 in *V. nimbaria* and 78 to 86 for *V. lucetia* given by Ahlstrom and Counts (1958) is also inclusive of the metamorphosing stages. The availability of more material of *V. nimbaria* will help more detailed comparisons between specimens from the different geographical areas as well as between the different species of the genus.

V. Development of Scales in *V. nimbaria*

The scales in *V. nimbaria* are very deciduous. On account of this it has been rather difficult to trace the developmental sequence of this character in the different growth stages.

VI. Development of the Adipose Fin in *V. nimbaria*

The earliest indication of the adipose fin is in the late larval stage just before metamorphosis. Its presence is noticeable in larvae about 11 mm. and upwards in total length as a slightly elevated ridge closer to the posterior base of the first dorsal fin than to the base of the caudal fin. By the postmetamorphic stage the adipose fin is fairly well developed (Fig. 8 b). In the related species *V. lucetia* according to Ahlstrom and Counts (1958) the adipose fin is not evident in the larvae but are seen on the postmetamorphosing individuals and is well developed by the end of metamorphosis.

VII. Spatial Distribution and Abundance of Larvae of *V. nimbaria* off the West Coast of India and the Laccadive Sea

The data on the distribution and abundance of larvae of *V. nimbaria* is based on collections obtained during the first 44 cruises of R. V. *VARUNA* (Fig. 12). Quantitative sampling with the Indian Ocean Standard net from April 1963 to December 1963 gives us some idea of the average abundance of the larvae in this area (Fig. 13). An apparent abundance of larvae along the continental shelf edge from south of Mangalore to off Quilon is noteworthy. Quantitative data being worked out for subsequent years will throw more light on the distribution and seasonal abundance of this species in this area.

A few points worthy of consideration are :

1. The species is found to occur more in the open sea than in neritic waters which has been rather intensively surveyed.

2. R. V. *VARUNA* undertook two special cruises to the equatorial waters of the Indian Ocean during the months September-October 1962 cruising between 70°E and 80°E longitude and from 7°N to 1°S latitude during which 75 plankton stations were occupied. It is interesting that larvae of *V. nimbaria* were not

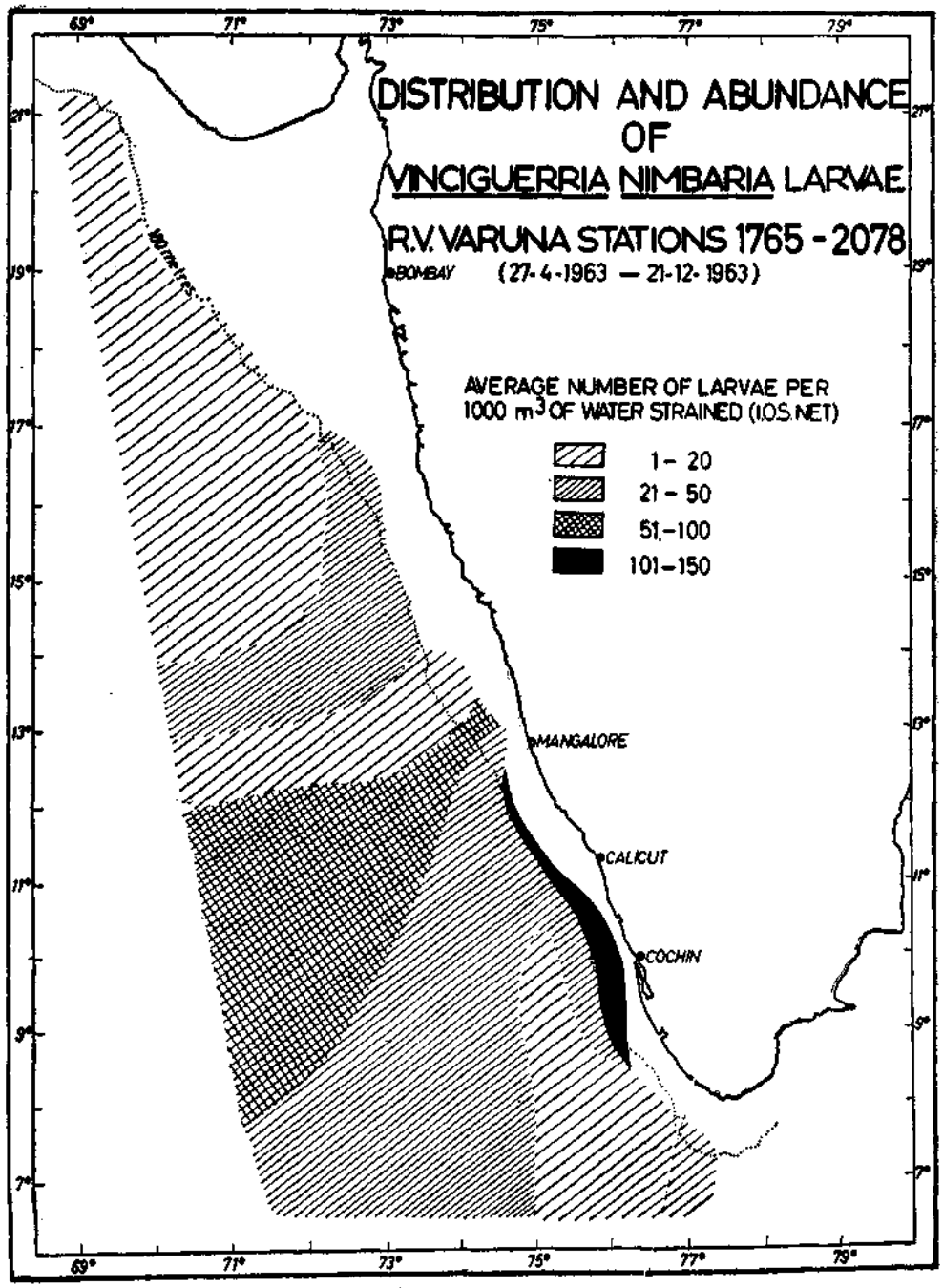

FIG. 13. Distribution and abundance of larvae of *V. nimbaria* off the west coast of India and the Laccadive Sea based on Indian Ocean Standard Net collections.

TABLE 8

Station list and other details of occurrence of Vinciguerria nimbaria *in the Arabian Sea and the northern Indian Ocean*

R.V. Varuna Station No.	Date	Time hours	Position		Gear used				Depth of haul in metres	Depth at station m.	No. of specimens caught	Size range in mm.
			Lat.	Long.	A Nansen net 70 cm. ring	B Mosquito net ½ m. ring	C Terylene net 1 m. ring	D IOS net 113 cm. ring				
852	23.2.62	1625-1720	08° 48′	75° 36′	×	—	—	—	100	300	1	13.3
942	2.4.62	1940-2025	15° 12′	72° 51′	×	—	—	—	100	234	2	7.0-13.3
943	,,	2130-2245	15° 10′	72° 41′	×	—	—	—	—	975	1	8.8
961	12.5.62	0209-0235	16° 42′	72° 28′	×	—	—	—	70	75	3	9.6-12.4
962	,,	0430-0505	16° 42′	72° 16′	×	—	—	—	95	100	2	6.9-9.0
966	,,	2015-2145	17° 24′	71° 33′	×	—	—	—	200	740	3	4.7-5.7
967	,,	2330-2400	17° 23′	71° 49′	×	—	—	—	120	125	1	6.0
984	14.5.62	2345-2400	18° 42′	70° 22′	×	—	—	—	85	90	1	11.5
985	15.5.62	0158-0215	18° 42′	70° 37′	×	—	—	—	80	88	1	8.5
986	,,	0400-0435	18° 42′	70° 52′	×	—	—	—	77	84	1	6.8
1070	23.6.62	2045-2230	09° 45′	75° 18′	×	—	—	—	80	1970	1	10.0
1071	,,	2345-0200	09° 41′	75° 07′	×	—	—	—	200	2300	1	7.9
1181	7.9.62	0730-0853	09° 04′	74° 32′	×	—	—	—	200	2640	2	8.5-14.2
1276	14.11.62	1120	08° 00′	75° 20′	×	—	—	—	100	3880	1	15.0

1290	16.11.62	1800-2055	08° 00′	75° 40′	—	×	—	—	200	2030	1	11.1
1296	17.11.62	1905	09° 20′	70° 00′	—	—	×	—	200	4530	1	12.6
1298	,,	2355	10° 00′	70° 00′	—	—	×	—	200	4420	2	8.6-15.5
1304	18.11.62	2155-2330	09° 56′	72° 08′	—	—	×	—	200	1040	4	7.9-15.0
1306	19.11.62	0330	10° 00′	72° 40′	—	×	×	—	100(B) 200(C)	1780	2	11.8-13.2
1310	,,	1700	10° 00′	74° 00′	—	×	—	—	50	2320	1	14.2
1312	20.11.62	0055-0214	10° 00′	74° 40′	—	—	×	—	300	2380	2	10.0-14.1
1316	,,	1510-1525	10° 00′	75° 50′	—	—	×	—	45	50	4	7.2-11.1
1371	13.12.62	0840	14° 00′	74° 00′	—	—	×	—	40	50	1	9.0
1373	,,	1348	14° 00′	73° 20′	—	—	×	—	200	230	1	8.7
1375	,,	—	14° 00′	72° 40′	—	—	×	—	200	1200	11	4.9-9.0
1377	14.12.62	0145	14° 00′	72° 00′	—	×	—	—	200	1600	2	9.0-13.1
					—	×	—	—	50	,,	15	7.4-14.2
					—	×	—	—	30	,,	18	8.2-13.2
					—	—	×	—	200	,,	38	6.9-12.4
1379	,,	0840	14° 00′	71° 20′	—	—	×	—	200	1960	2	8.2-10.2
1383	,,	2220	14° 00′	70° 00′	—	—	×	—	200	3900	2	9.5-10.0
1385	15.12.62	0335	14° 25′	70° 00′	—	×	—	—	30	3580	5	5.4-14.4
					—	×	—	—	0	,,	5	7.4-15.6
					—	—	×	—	200	,,	5	7.2-13.4
1389	,,	1740	14° 49′	70° 40′	—	×	—	—	30	3000	2	8.3-9.3
					—	×	—	—	75	,,	1	damaged, post-metamorphic stage
1391	16.12.62	0112	14° 49′	71° 20′	—	—	×	—	200	2080	34	4.9-14.1
1393	,,	0800	14° 49′	72° 20′	—	—	×	—	200	2020	2	5.5-7.7
					—	×	—	—	30	,,	1	12.4
1397	,,	2110	14° 49′	73° 20′	—	×	—	—	30	83	5	7.2-10.9
1407	6.1.63	1955-2010	16° 00′	73° 05′	—	×	—	—	30	70	1	9.5
					—	—	×	—	65	,,	3	9.5-14.8
1409	,,	2305	16° 00′	72° 43′	—	×	—	—	30	,,	7	5.8-13.6
					—	×	—	—	50	125	4	5.2-11.1
					—	×	—	—	100	,,	3	8.2-12.2
1411	,,	0050-0730	15° 58′	72° 03′	—	—	×	—	100	,,	9	4.6-12.4
					—	×	—	—	200	1720	12	6.5-11.1
									200	,,	1	14.8

TABLE 8

Station list and other details of occurrence of Vinciguerria nimbaria *in the Arabian Sea and the northern Indian Ocean—(Continued)*

R.V. Varuna Station No.	Date	Time hours	Position		Gear used				Depth of haul in metres	Depth at station m.	No. of specimens caught	Size range in mm.
			Lat.	Long.	A Nansen net 70 cm. ring	B Mosquito net ½ m. ring	C Terylene net 1 m. ring	D IOS net 113 cm. ring				
1413	7.1.63	1250	16° 02′	71° 22′	—	×	—	—	100	2200	51	5.3-13.3
					—	×	—	—	50	,,	1	7.6
					—	×	—	—	30	,,	1	8.8
1415	,,	1940	16° 00′	70° 40′	—	×	—	—	100	3350	13	4.3-12.2
					—	—	×	—	200	,,	1	14.3
					—	×	—	—	—	,,	20	4.0-12.4
1417	8.1.63	0305	16° 00′	69° 59′	—	×	—	—	200	3600	3	15.0-17.5
					—	×	—	—	75	,,	11	7.1-16.3
					—	×	—	—	50	,,	1	19.3
					—	×	—	—	100	,,	17	5.7-15.4
					—	—	×	—	200	,,	10	9.3-14.2
1419	,,	1045	16° 43′	69° 48′	—	×	—	—	100	3500	1	8.6
					—	×	—	—	0	,,	1	13.8
1421	8.1.63	1800-2025	17° 00′	70° 20′	—	×	—	—	50	3270	1	17.4
					—	×	—	—	30	,,	1	12.6
					—	×	—	—	0	,,	1	14.5
1423	9.1.63	0100-0330	17° 00′	71° 01′	—	—	×	—	100	2520	3	7.5-9.3
					—	×	—	—	50	,,	2	7.2-11.7
1425	,,	0810	16° 53′	71° 40′	—	×	—	—	30	1200	3	7.2-8.1
1437	10.1.63	0515	15° 37′	73°31′	—	—	×	—	30	34	2	13-3-15.0
1441	to 1681 :	Stations on east coast of India not included in the studies.										
1696	10.4.63	2340	08° 08′	77° 10′	—	×	—	—	35	40	1	8.8
1704	11.4.63	2230	08° 00′	76° 38′	—	—	×	—	200	600	1	9.1
1705	12.4.63	0010	08° 14′	76° 46′	—	—	×	—	75	77	2	10.2-12.9
1720	18.4.63	—	08° 24′	75° 48′	—	×	—	—	30	1250	1	17.6
1723	19.4.63	1808-2010	06° 57′	77° 32′	—	—	×	—	200	2280	1	16.0
1725	20.4.63	—	07° 12′	77° 32′	—	—	×	—	200	280	1	11.1
1727	,,	0430-0515	07° 32′	77° 32′	—	×	—	—	75	93	1	8.0
					—	—	×	—	90	,,	2	7.1-96.
		2045			—	×	—	—	30	,,	3	6.7-7.1

1732	,,	2130-	08° 08′	76° 36′	—	×	—	—	50	220	2	12.5-13.8
1733	21.4.63	0405-0500	08° 57′	76° 00′	—	—	×	—	200	288	1	16.8
1746	25.4.63	1110-1245	12° 35′	74° 05′	—	×	—	—	200	716	1	7.4
1748	,,	1645-1900	12° 29′	73° 46′	—	×	—	—	200	1720	1	6.5
1749	26.4.63	0045-0300	11° 40′	73° 59′	—	×	—	—	100	1250	1	12.0
					—	—	×	—	500	,,	4	6.6-10.2
1750	,,	0410-0630	11° 43′	74° 09′	—	×	—	—	100	1250	3	8.2-12.4
					—	—	×	—	200	,,	1	11.1
1752	,,	1025-1140	11° 48′	74° 29′	—	—	×	—	200	250	1	12.6
1764	27.4.63	1315-1440	10° 54′	74° 30′	—	—	×	—	200	1250	1	7.0
1780	8.5.63	2130-2200	21° 06′	69° 03′	—	—	—	×	85	90	1	8.4
1982	19.10.63	0020-0320	09° 33′	73° 59′	—	—	—	×	200	2420	8	8.9-16.2
1986	21.10-63	1630-1925	12° 15′	72° 53′	—	—	—	×	200	2040	14	7.2-12.9
1987	,,	2145-2400	12° 22′	73° 12′	—	—	—	×	200	,,	2	6.0-8.6
2000	2.11.63	1825-1910	07° 48′	76° 28′	—	—	—	×	200	1300	3	19.0-24.5
2001	3.11.63	0100-0340	07° 30′	76° 10′	—	—	—	×	200	1520	2	16.5-16.6
2014	6.11.63	1810-2305	09° 10′	70° 40′	—	—	—	×	200	4400	14	7.7-16.3
2017	16.11.63	2055-2145	10° 57′	75° 07′	—	—	—	×	200	220	5	10.6-16.0
2022	17.11.63	1615-1840	09° 41′	75° 10′	—	—		×	200	2460	1	11.1
2023	,,	2040-2305	09° 45′	75° 26′	—			×	200	1600	5	12.3-16.2
2025	,,	0235-0300	09° 53′	75° 53′	—	—	—	×	40	60	5	8.2-16.8
2026	18.11.63	0410-0435	09° 54′	76° 04′	—	—	—	×	25	34	3	9.6-12.4
2033	7.12.63	—	16° 10′	72° 25′	—	—	—	×	100	—	5	5.4-22.1
2034	,,	2320	16° 06′	72° 10′	—	—	—	×	200	1660	7	4.7-16.7
2035	8.12.63	0425	16° 01′	71° 56′	—	—	—	×	200	2000	2	5.7-16.1
2036	,,	0945	15° 37′	71° 22′	—	—	—	×	200	2600	4	7.4-15.6

TABLE 8

Station list and other details of occurrence of Vinciguerria nimbaria *in the Arabian Sea and the northern Indian Ocean—(Continued)*

R.V. Varuna Station No.	Date	Time hours	Position		Gear used				Depth of haul in metres	Depth at station m.	No. of specimens caught	Size range in mm.
			Lat.	Long.	A Nansen net 70 cm. ring	B Mosquito net ½ m. ring	C Terylene net 1 m. ring	D IOS net 113 cm. ring				
2039	9.12.63	1900	15° 03′	71° 32′	—	—	—	×	200	2000	4	6.9-15.5
2054	12.12.63	0445-0730	14° 23′	72° 52′	—	—	—	×	200	1920	8	4.5-16.5
2059	,,	1945-2004	13° 36′	73° 40′	—	—	—	×	50	66	1	15.5
2071	19.12.63	1850-2045	09° 30′	73° 50′	—	—	—	×	200	2420	2	10.9-15.5
2074	21.12.63	0035-0205	12° 20′	73° 12′	—	—	—	×	200	1200	13	4.2-17.3
2075	,,	0440-0620	12° 28′	73° 32′	—	—	—	×	200	1220	14	6.0-17.6
2078	,,	1304-1320	12° 44′	74° 24′	—	—	—	×	50	60	2	7.3-8.5

obtained from vertical and oblique plankton tows from this area except a few from off the Wadge Bank.

3. Plankton collections made during the routine cruises of R. V. *VARUNA* in January and March 1962 ; July and August 1962 and 1963 ; September 1963 ; and October 1962 from off the west coast and the Laccadive Sea did not contain larvae of *V. nimbaria.*

4. Routine cruises undertaken between April and May 1962 and 1963 show the occurrence of larvae from mostly off the edge of the continental shelf.

As will be seen from Table 8, collections made during the months November to January indicate relatively larger number of specimens in the larval stage. There appears to be a similar abundance of larvae over a wide area off the west coast of India during the months April-May. The data available to us does not warrant generalization as to the peak spawning period of this species.

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