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STUDIES ON THE LARVAL DEVELOPMENT OF THE COMMERCIALLY IMPORTANT PENAEID PRAWNS OF INDIA*

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ABSTRACT

With the increased commercial importance of penaeid prawns, studies on the larval development of this group have received much attention during the last two decades. Although a number of penaeid prawns contribute to the prawn fishery of India, details of larval development of only a single species, *Metapenaeus dobsoni* (Miers) are known.

In the present paper, the egg, five nauplial, three protozoeal, three mysis and ten postlarval substages of *Parapenaeopsis stylifera* (H. Milne-Edwards); three mysis and nine postlarval substages of *Metapenaeus monoceros* (Fabricius); three mysis substages of *M. affinis* (H. Milne-Edwards); five nauplial, three protozoeal, three mysis and seven postlarval substages of *M. dobsoni* (Miers); three mysis and seven postlarval substages of *Penaeus indicus* H. Milne-Edwards have been described and figured. While the larval development of these species generally follows similar pattern with many common features, comparison of different stages reveals that characters such as length of rostrum, presence or absence of supraorbital spine on carapace, setation of antenna, nature of antennal scales, spination of abdominal segments as well as telson and pigmentation show specific differences and help in the identification of the larvae of these larval forms Based on these characters a key for the identification of the larvae of the different species studied has been prepared. The variations recorded in the number of substages of the larval forms have been discussed.

INTRODUCTION

WITH the development of new techniques for rearing larval crustaceans, a series of studies on the larval development of penaeid prawns (Gurney, 1927; Hudinaga, 1935, 1942; Heldt, 1933; Pearson, 1939; Menon, 1951; Muriel and Bennett, 1951, Heegaard, 1953; Williams, 1953, 1955, 1959; Dobkin, 1961; Renfro and Cook; 1962; Cheung, 1963; Cook, 1965; Cook and Murphy, 1966, 1969, 1971; Lee and Lee, 1968, 1969; Kirkegaard, 1969 and Al-Kholy and El-Hawary, 1970) are now available. However, the investigations on the larval history of Indian penaeid prawns are limited. Menon (1937) described the protozoea and mysis I stages of *Penaeus indicus* obtained from plankton collections from Madras. Later, the same author (Menon, 1951) gave a detailed description of the early life history of *Metapenaeus dobsoni* dealing with eggs, three nauplial, three protozoeal, three mysis and seventeen postlarval stages obtained from plankton. Subrahmanyam (1965) assigned the eggs collected from coastal waters of Madras to *P. indicus* and added three nauplial stages to the incomplete work of Menon (1937). Recently, Mohamed, Rao and George (1968) described and compared the first postlarval stage of *P. indicus, M. dobsoni, M. monoceros, M. affinis* and *Parapenaeopsis stylifera*.

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Considering the importance of penaeid prawns in the economy of the country and the possibility of improving their fishery, both capture and culture through biological investigations of the individual species, the present study on the larval development of five species, namely, *Parapenaeopsis stylifera* (H. Milne-Edwards) *Metapenaeus monoceros* (Fabricius), *M. affinis* (H. Milne-Edwards), *M. dobsoni* (Miers) and *Penaeus indicus* H. Milne-Edwards was undertaken as part of the overall investigations on the biology of these species.

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MATERIAL AND METHODS

The larvae were obtained from the plankton collections made off Cochin Barmouth and from the adjoining backwaters. The plankton tows were of ten minutes duration, generally made with an organdy net of half a metre diameter during the early hours of the morning at subsurface waters. The net was usually operated against the current. As soon as the net was hauled up, the plankton was transferred to a plastic vessel containing water collected from the same area of collection. The live plankton was transported to the laboratory for detailed examination.

In the laboratory, the active and healthy larvae were carefully picked out with a wide mouthed pipette for rearing experiments. The rest of the plankton was preserved in 5% formaldehyde for further detailed studies. Colouration of the larvae were recorded before preservation.

The larvae used for descriptive purposes were taken mainly from the preserved material. Sketches were made with the aid of camera lucida and the dissection of appendages was performed in 85% lactic acid. The measurements of larvae were taken to the nearest 0.016 mm with the help of an ocular micrometer. The total length was measured from the anterior part of the body to the posterior end excluding the spines up to protozoea I substage, and from the tip of rostrum to the apex of telson excluding spines for the larval stages above protozoea I. The carapace length was taken from the postorbital margin to the mid-dorsal termination of the carapace.

In the laboratory, the active larvae picked out from the plankton were reared in glass containers such as beakers (250-500 ml) and troughs (5000 ml) containing filtered sea water to which the metal chelator, EDTA, was added. The medium in the containers was changed daily. The diagnostic characters of the larvae described and illustrated in this paper were verified from both the material obtained from plankton as well as rearing.

Protozoeal substages were fed with cultures of diatoms, *Skeletonema* sp., *Navicula* sp. and unicellular green alga, *Chlamydomonas* sp. For the later stages, freshly hatched *Artemia* nauplii were given. The advanced postlarvae were fed with bits of earth worm, unsorted live plankton and minced meat of fresh water gastropod.

Temperature of the medium in rearing experiments raged from 26° C to 30° C and the salinity from 31.36‰ to 35.83‰. When the temperature reached above 30°C, it was controlled by keeping the rearing vessel in a water bath.

The following abbreviations are used in the text of the paper:

Tl-Total length; Cl-Carapace length; Gbw-Greatest body width; C-Carapace; Al-Antennule; A2-Antenna; Md-Mandible; Mxl-First maxilla; Mx2-Second maxilla; Mxpl-First maxilliped; Mxp2-Second maxilliped; Mxp-3 Third maxilliped; Per-Pereopod; Ab-Abdomen; Ab. Seg-Abdomial segment; U-Uropod and T-Telson.

DESCRIPTION OF LARVAL STAGES

Parapenaeopsis stylifera (H. Milne-Edwards)

Egg:

Eggs spherical and of a bluish tint, with a central opaque embryonic mass which does not fill egg membrane completely; perivitelline space wide; diameter of egg, 0.400 mm to 0.432 mm and that of embryonic mass enclosed by thin embryonic membrane, 0.240 mm.

The eggs collected from the plankton were in advanced stages of development and the earliest stage encountered had already completed segmentation (Fig. 1a). In the next stage (Fig. 1b), the rudiments of three pairs of naupliar appendages developing as buds from the embryonic mass were present. In the more advanced stage, distinct outline of the nauplius with further enlarged appendages, but enclosed in the embryonic membrane, could easily be made out. In the final stage (Fig. 1c), just before hatching, the embryonic membrane remained ruptured and the nauplius was seen to lie inside the egg membrane with the appendage partly straightened out.

Nauplius I (Fig. 1d): Tl-0.25-0.27 mm; Gbw-0.15-0.17 mm.

Body opaque, pear-shaped, broader anteriorly with three pairs of appendages, and with no trace of internal organs or segmentation; posterior end of body rounded with a pair of setae; a short cresent-shaped labrum without any palp present ventrally; a median nauplial eye present. Al-uniramous, unsegmented and distally with 2 long and 1 short setae; A2-biramous, unsegmented; exopod longer than endopod, with 3 setae on inner margin and 2 at tip; endopod bears 2 small, rudimentary setae anterolaterally and 2 longer setae distally; Md-short, biramous, each branch with 3 terminal setae.

Nauplius II (Fig. 1e): Tl-0.30-0.32 mm; Gbw-0.17-0.18 mm.

General shape of body similar to that of Nauplius I, but the posterior region slightly elongated, with a median notch differentiating the furcal processes which later develop into telson lobes; each process carries 3 setae, the median of which is longer; the nauplius eye persists at anterior end; the longer setae of appendages plumose. Al-uniramous, unsegmented with 2 small inner and 3 unequal setae distally; A2- biramous, unsegmented; exopod with 3 setae on inner margin and 4 at apex; endopod with 3 apical and 2 lateral setae; Md- exopod and endopod with 3 long setae.

Nauplius III (Fig. 1f): Tl-0.32-0 35 mm; Gbw-0.18-0.20 mm.

Posterior region of body more elongated, furcal processes further developed and distinct, each process carrying 4 spines, the second from inner-most being longest; median eye persists and appendages show segmentation. Al-basal portion faintly segmented; setation as in previous substage; A2-composed of

indistinctly segmented protopod, an endopod of 2 and an exopod of 7 segments; setation unchanged; a bump-like process develops at base of Md; two rami of Md carry same number of setae as in previous substage.

Nauplius IV (Fig. 1g) Tl-0.35-0.38 mm; Gbw-0.20-0.23 mm.

Body more slender and posterior region further elongated; furcall spines increase to 6+6; median eye persists; posterior margin of labrum more acute; rudiments of Mxl-2 and Mxpl-3 appear posterior to mandibular appendages, they are biramous and non-functional. Al-basal portion distinctly 5-subsegmented, though setation remains unchanged; A2-protopod 2-segmented; exopod 8-segmented, with 4 inner and 4 terminal setae; endopod as in previous substage; Md-basal swelling further enlarged; setation unchanged.

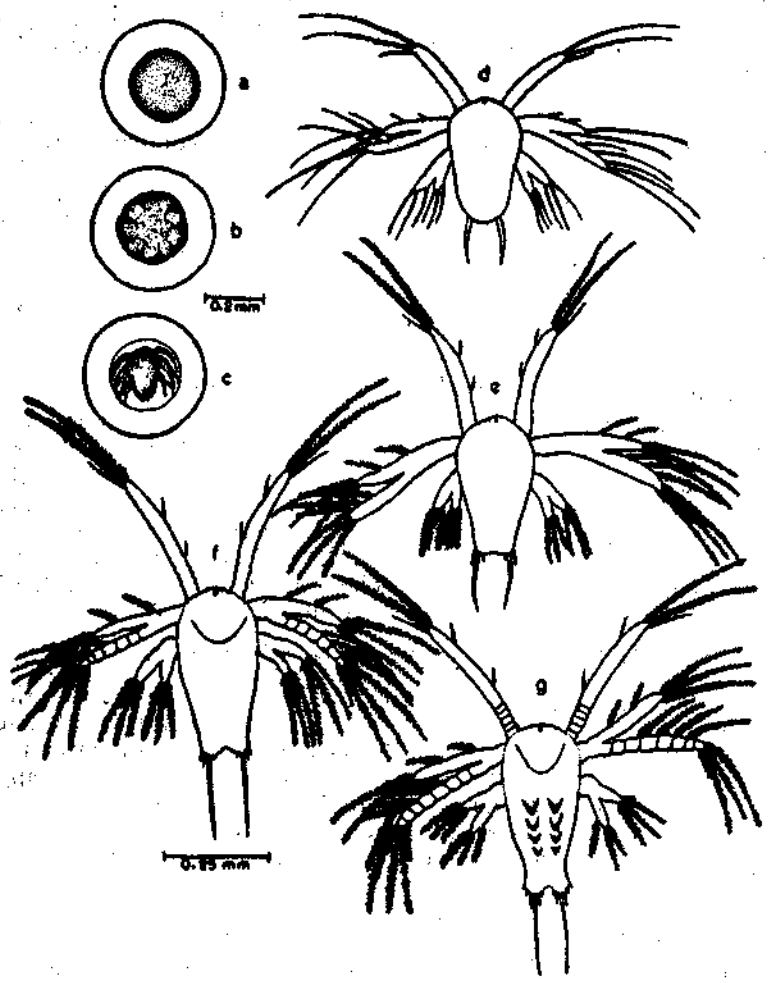

Fig. 1. *Parapenaeopsis stylifera* – a. Egg, segmentation completed, b. Embryo with appendage bud, c. Egg-with nauplius inside, d Nauplius I (dorsal view), e. Nauplius II (dorsal view), f. Nauplius III (ventral view), and g. Nauplius IV (ventral view).

Nauplius V (Fig. 2a): Tl-0.38-0.40 mm; Gbw-0.20-0.23 mm.

Body more transparent and posteriorly slender; rudiment of carapace appears as a transverse fold on dorsal surface near middle of body; caudal lobes well developed, each lobe having 7 spines, 3rd and 4th from outer margin being longer than others. Al-uniramous, basal portion with 5 subsegments; 3 terminal setae of unequal length and 3 inner lateral setae, situated one each at base, middle and near apex; A2-same as in Nauplius IV; basal swelling of Md very prominent and develops a spherical masticatory surface; endopod transparent and setation unchanged; Mxl-2 and Mxpl-3 biramous and more developed, occupying a major portion of ventral surface between labrum and caudal lobes; minute setae present at tip of these appendages.

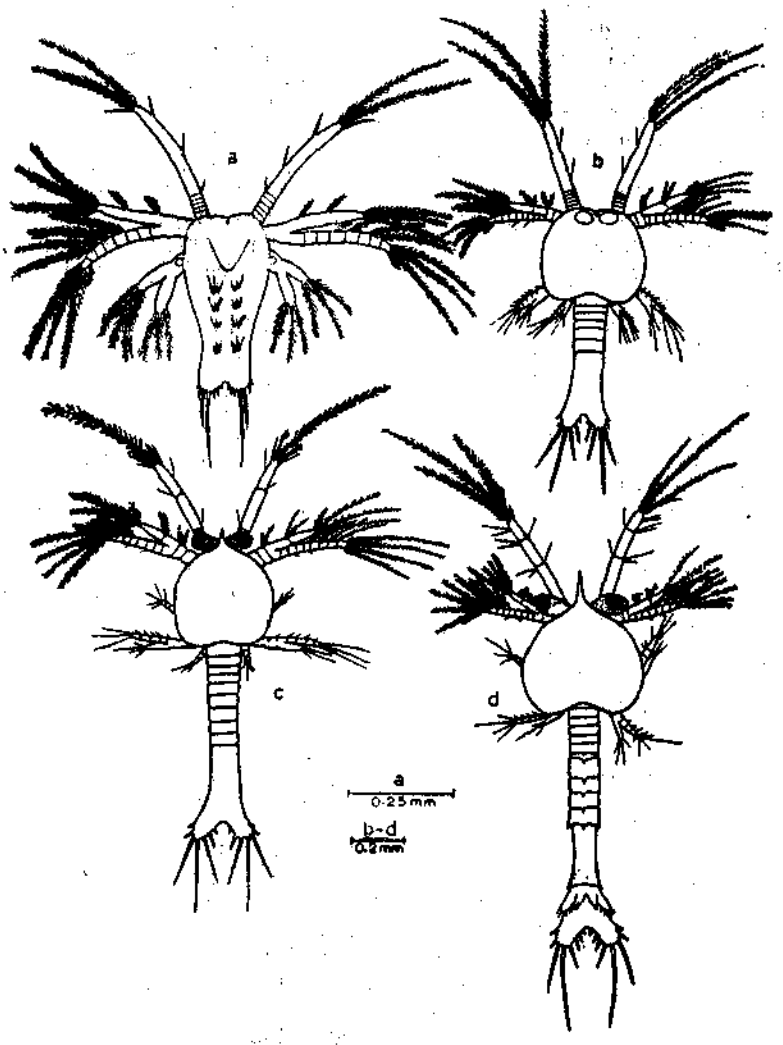

Fig. 2. *Parapenaeopsis stylifera* – a. Nauplius V (ventral view), b. Protozoea I (dorsal view), c. Protozoea II (dorsal view), and d. Protozoea III (dorsal view).

Protozoea I (Fig. 2b) : Tl-0.68-0.85 mm; Cl-0.30-0.35 mm.

As in the typical development of penaeid larvae, the transformation of Nauplius V to protozoea I results in profound changes in the general morphology of the larva.

Body divisible into 3, an anterior part covered dorsally by carapace followed by a segmented thorax and posteriorly an unsegmented abdomen; anteriorly carapace semicircular with a median notch; naupliar eye still present between a pair of sessile compound eyes visible underneath the carapace; labrum small with rounded posterior edge, followed by bilobed labium and mandibles; digestive tract of larva discernible. Al-uniramous, segmentation indistinct though basal segment divided into 5 subsegments, penultimate segment longest with a short lateral seta at mid-length, terminal segment with 3 unequal setae at tip and 1 short seta each on inner and outer lateral margins; A2 (Fig. 3a)- biramous; protopod and endopod 2-segmented; distal segment of endopod with 3 long and 1 short terminal setae; 2 pairs of characteristically placed lateral setae arise from notches of joints; exopod 9 or 10 segmented, of which 4th to 9th segments with lateral setae, and terminal segment with 4 long setae; segments 3 and 5 each with a short seta on its distolateral margin; Md (Fig. 3b)- flattened, with serrated inner margin, both endopod and exopod absent from this stage onwards; ventrally cutting edge with a large tooth followed by 2 smaller pointed teeth and dorsally with 4-5 small teeth; Mxl (Fig. 3c)-protopod bilobed, each lobe carrying about 7 setae; endopod 3-segmented, first 2 segments with 2 setae each, 3rd with 4 setae; exopod small, knob-like, with 4 long plumose setae; Mx2 (Fig. 3d)-protopod with 5 lobes, basal lobe with 6 setae, 2nd and 3rd with 3 setae each and 4th and 5th each with 2 setae; endopod 4-segmented, each segment with 2 setae; exopod with 5 plumose setae; Mxpl (Fig. 3e)-protopod 2-segmented, each segment with 4 or 5 setae; endopod 5 segmented, 1st to 4th segments each with 2 outer setae and terminal segment with 5 apical setae; exopod unsegmented, about 3/4 as long as endopod and with 4 terminal and 2 lateral setae; Mxp2 (Fig. 3f)-smaller than Mxpl; protopod 2-segmented, each segment with 4 or 5 setae; endopod 4-segmented, 1st to 4th segments with single lateral setae at outer base and terminal segment with 4 apical setae; exopod unsegmented with 6 setae along lateral margin and tip; behind Mxp2 thoracic segments discernible, but appendages rudimentary; Ab-unsegmented; T-bilobed, each lobe with 7 spines median of which longer.

Protozoea II (Fig. 2c): Tl-1.25-1.50 mm; Cl-0.38-0.40 mm.

Carapace with a rostrum, but devoid of spines; compound eyes free of carapace, stalked and movable, extending beyond rostrum when bent forward; posteriorly carapace extends to 4th or 5th thoracic segment. Al (Fig. 3g)-segmentation more distinct; distal segment bears 4 small and 1 very long setae; A2 (Fig. 3h)-same as in previous substage; Md (Fig. 3i)-posterior to large tooth are present 5 long, slender and pointed teeth; molar surface with irregular cusps more marked; no significant changes in the structure of Mxl (Fig. 3j), Mx2 (Fig. 3k), Mxpl (Fig. 3l) and Mxp2 (Fig. 3m); Mxp3 (Fig. 3n) small with indistinctly 2-segmented protopod, 4-segmented endopod; and an unsegmented exopod; other thoracic appendages rudimentary; all thoracic and 6 Ab. seg. distinct; 6th Ab. seg. very much longer than others; T-each lobe continues to carry 7 spines.

Protozoea III (Fig. 2d) : Tl-1.45-1.73 mm; Cl-0.43-0.50 mm.

Presence of spines on Ab. seg. and development of uropod are characteristic features of this substage; anteriorly carapace carries a rostrum and posteriorly extends to first five thoracic segments; compound eyes with stout stalks conspicuous; Al (Fig. 3o)-3 segmented, 5 subsegments of basal segment seen in protozoea II united to form a single segment; A2 (Fig. 3p), Md (Fig. 3q), Mxl (Fig. 3r), Mx2 (Fig. 3s), Mxpl and Mxp2 (Fig. 3t) remain essentially the same as in previous substage; Mxp3 (Fig. 3u) and Per, 1-5, develop further and the latter biramous; combined length of first five Ab. seg. longer than that of thorax, each segment with a backwardly directed dorsomedian spine on its posterior border and 5th segment, in addition, with a pair of posterolateral spines; 6th, which is the longest, also carries a spine on each posterolateral corner; U-biramous; exopod slightly longer and bears 5 setae; endopod carries 2 small setae at tip; T-separated from 6th Ab. seg. and each lobe with 8 spines.

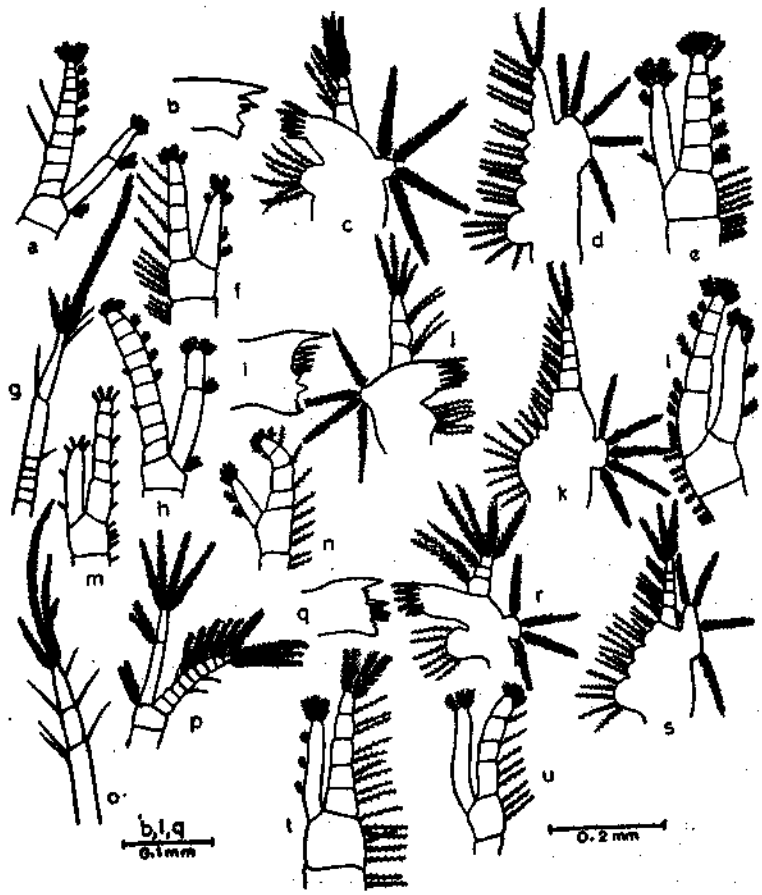

Fig. 3. *Parapenaeopsis stylifera* – A2 of protozoea I, b. Md of same, c. Mx1 of same, d. Mx2 of same, e. Mxp1 of same, f. Mxp2 of same, g. A of protozoea II, h. A2 of same, i. Md of same, j. Mx1 of same, k. Mx2 of same, l. Mxp1 of same m. Mxp2 of same, n. Mxp3 of same, o. A1 of protozoea III, p. A2 of same q. Md of same, r. Mx1 of same, s. Mx2 of same, t. Mxp2 of same, and u. Mxp3 of same.

Mysis I (Fig. 4a) : T1-1.98-2.78 mm; C1-0.55-0.70 mm.

Remarkable development of carapace and thoracic appendages take place during metamorphosis of protozoea III to mysis I, the latter assuming a shrimp-like form; body divisible into an anterior cephalothoracic region and a slender posterior abdomen; eyes well developed, conical and with stout stalks; C-extends posteriorly covering most of thorax; rostrum slender, slightly curved ventrally and extends to 3/4 length of eye; antennal and pterygostomial spines present; A1 (Fig. 4b)-3 segmented, basal segment longest, having a small basal swelling representing developing statocyst, besides a spine on inner side at about mid-length of segment; 3rd segment bears 2 unsegmented flagella which are still rudimentary; inner being smaller with 2 setae and the outer longer with 6 or 7 setae; all the three segments of A1 beset with a series of plumose setae; A2 (Fig. 4c)-protopod 2-segmented; exopod flattened to form antennal scale and beset with 12 or 13 plumose setae along inner and terminal margins, a small spine also present at outer anterolateral margin; endopod unsegmented, rod-like and about 1/2 length of scale, tip carries 2 setae; Md (Fig. 4d)-on ventral side a stout tooth, followed by a series of long and slender teeth present, of latter posterior 4 or 5 serrated; palp rudimentary; Mx1 (Fig. 4e), Mx2 (Fig. 4f) remain unchanged, except that exopod of the latter enlarges to form scaphognathite which now bears 7 setae; Mxp1 (Fig. 4g) and Mxp2 (Fig. 4h) essentially same as in preceding substage; Mxp3 (Fig. 4i)-longer and slender than Mxp1 and 2; protopod 2-segmented; endopod 4-segmented, distal segment with 4 or 5 apical setae; exopod unsegmented and slender, being about 3/4 of endopod and with 5 terminal setae; Per-well developed and bear long setae, first three indistinctly chelate, each with a 2-segmented endopod and an unsegmented exopod; Per-4 and 5 smaller; Ab-a prominent posterior median dorsal spine on 5th and 6th segments, latter segment elongated and about 2.5 times as long as 5th; U (Fig. 4j)- with a short protopod; exopod with 12 or 13 setae and a small subterminal spine on outer margin; endopod with 9 to 12 setae; T (Fig. 4j)-with prominent median notch and 8 pairs of spines, 5 pairs on posterior margin and 3 pairs on posterolateral margin, 4th spine from outer margin longest.

Mysis II (Fig. 4k) : T1-3.32-3.38 mm; C1-0.72-0.85 mm.

C-well developed, completely covers thoracic segments; a small hepatic spine, in addition to antennal and pterygostomial spines present; rostrum with a small dorsal tooth; A1 (Fig. 4 l)-a round statocyst present on swelling of basal segment, swelling bordered dorsally with three stout setae; flagella unjointed, inner slightly smaller and almost equal in length to 3rd segment of peduncle; a number of setae present on segments; A2 (Fig. 4m)-flagellum slender and unsegmented, about 2/3 length of scale, latter beset with 20 setae along inner and terminal borders; anterolateral spine conspicuous; Md (Fig. 4n)-palp slightly elongated, but unsegmented; Mx1 (Fig. 4o)-exopod disappears; Mx2 (Fig. 4p)-scaphognathite increases in size and bears 13 or 14 setae on anterior and posterior borders; Mxp1 (Fig. 4q)-Mxp3 - almost same as in previous substage; Per-increase in size, first three chelate, 3rd pair longest; Ab-first five segments carry pleopods, small, uniramous, non-functional; dorsomedian spine on 5th and 6th segments persists; U (Fig. 4r)-same as in previous substage, except for increase of setation in exopod and endopod; T (Fig. 4s)-median notch shallow and inconspicuous, with 8 pairs of spines, anterior pair of posterolateral spines separated by some distance from remaining two pairs.

Mysis III (Fig. 4t): T1-4.08-4.17 mm; C1-1.00-1.38 mm.

Larva of this substage is characterised by well developed and two segmented pleopods and telson with a straight posterior margin.

C-rostrum extends to 3/4 eye and bears 2 dorsal teeth and a minuate epigastric; other spines on carapace same as in previous substage; A1 (Fig. 4u)-statocyst well developed; outer flagellum indistinctly segmented and inner

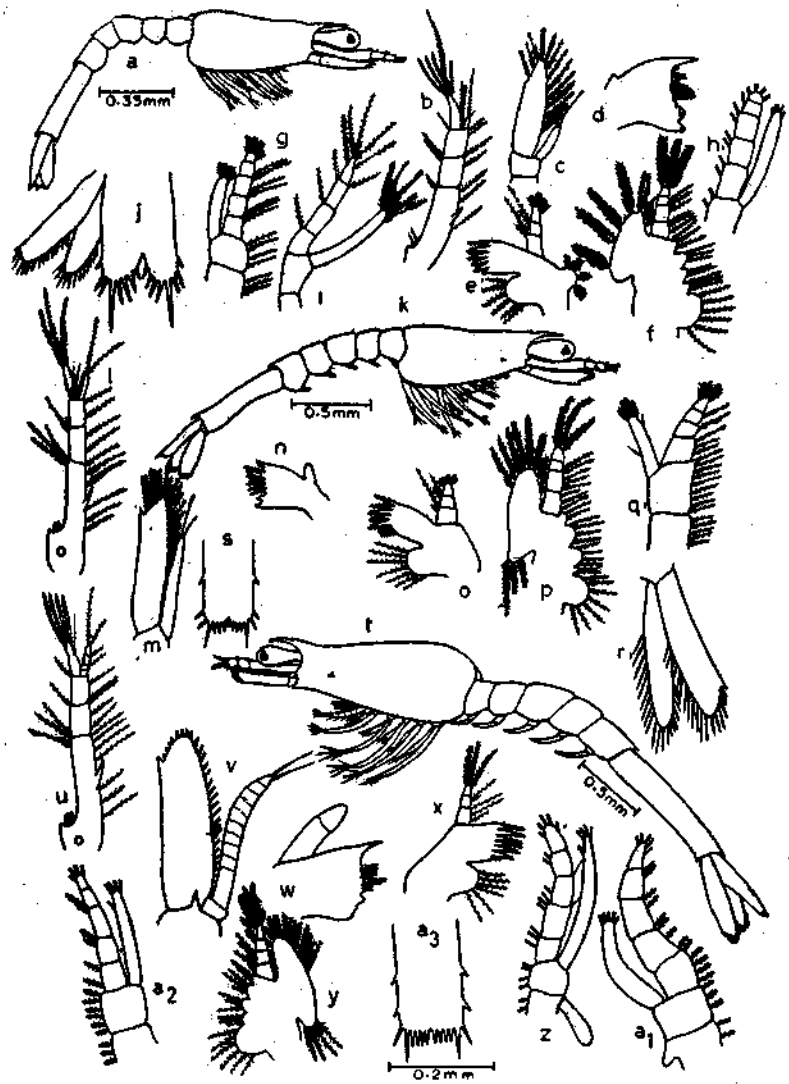

Fig. 4. *Parapenaeopsis stylifera* – a. Mysis I (side view), b. A1 of same c. A2 of same, d. Md of same, e. Mx1 of same, f Mx2 of same, g. Mxp1 of same, h. Mxp2 of same, i. Mxp3 of same, j. uropod and telson of same, k. Mysis II (side view), l. A1 of same, m. A2 of same, n. Md of same. o. Mx1 of same, p. Mx2 of same, q. Mxp1 of same, r. Uropod of ame, s. tip of telson of same, t. Mysis III (side view), u. A1 of same, v. A2 of same, w. Md of same, x. Mx1 of same, y. Mx2 of same, z. Mxp1 of same, a_1. Mxp2 of same, a_2. Mxp3 of same, and a_3. Tip of telson of same.

3-segmented; A2 (Fig. 4v)-flagellum long, composed of about 11 segments, distal segment carrying 2 setae; scale with 26 setae and a conspicuous distolateral spine; protopod with an anterior median spine; Md (Fig. 4w)-palp well developed, 2-segmented; teeth on cutting edge almost same as in previous substage; Mx1 (Fig. 4x)-same as in previous substage; Mx2 (Fig. 4y)-scaphognathite well developed, with 19 or 20 setae; Mxp1 (Fig. 4z), Mxp2 (Fig. $4a_1$) and Mxp3 (Fig. $4a_2$)-same as in previous substage, except that rudiment of gill appear in Mxp1 and Mxp2; Per-first three chelate; endopod 5-segmented; exopod of Per1 and Per2 short, of Per3 about 1/2 endopod, of 4th and 5th 4-segmented; Ab-pleopods well developed, each 2-segmented, but without setae; U-almost same as in previous substage; T (Fig. $4a_3$)-elongated, without posterior median notch; 8 pairs of spines as in previous substage, but posterolateral spines placed wide apart.

Postlarva I: Tl-4.32-5.05 mm; Cl-1.29-1.50 mm.

First postlarva of *P. stylifera* has been described by Mohamed, Rao and George (1968). Rostrum reaching almost middle of eye stalk, with 2 dorsal and a minute epigastric spines; carapace with well developed antennal and small hepatic spines; mouth parts show only minor changes from those of mysis III; Per 1 to 3 chelate, 3rd pair being longest and extending forward to middle of antennal scale; pleopods well developed, uniramous and functional; none of ab. seg. bear dorsal median spine, but median ventral margin of 6th segment pointed; T bears 3 pairs of lateral and 11 posterior spines: median posterior spine very large and almost equal in length to large outermost pair of posterior spines; posterior margin between outermost pair of posterior spines tapers towards middle spine.

Advanced postlarvae:

During the present study, a series of ten postlarval stages measuring from 4.33 mm to 17.63 mm were recognised (Table 1) and the important changes undergone are summarised below:

TABLE 1. *Postlarval substages of* P. stylifera

Substage	Tl (mm)	(Cl mm)
I	4.33–5.05	1.29–1.30
II	5.53–5.79	1.30–1.58
III	5.7 –6.00	1.50–1.59
IV	6.75–7.55	1.65–2.00
V	7.88–8.33	2.00–2.35
VI	9.35–9.53	2.45–2.50
VII	11.23	2.95
VIII	13.90	3.15
IX	15.53	3.97
X	17.63	4.19

C and rostrum (Fig. 5a to 5f)-length of rostrum in postlarva I and postlarva II almost 1/2 as long as eye, but it gradually increases in subsequent moults being 3/4 of eye in postlarva III and as long as eye in postlarva V, rostrum thereafter, extending beyond eye attaining almost double length of eye in postlarva X; number of dorsal tooth on rostrum gradually increases from 4 in postlarva II to 8 in postlarva X, sequence of development of tooth varying in individual specimens, a minute tooth seen at one substage becoming well developed in the next moult; postlarvae may undergo more than one moult retaining the same number of teeth on rostrum; no significant morphological changes in carapace, except that antennal and hepatic spines developed in mysis stage grow longer and stronger; Ab-no great change in Ab. seg. 1-5, Ab. seg. 6 longer than

other segments in early postlarvae, becoming shorter in later stages; posteromedian dorsal spine reduced in postlarva II; T and U- in telson (Fig. 5g to 5k), the spines between outermost posterior one and median one slightly smaller in postlarva II; tip of telson becomes conspicuous and projects outward in postlarva III and above mentioned small marginal spines become minute, disappearing completely in postlarva IV, the latter substage also characterised by arrangement of terminal and two inner lateral spines in "tridentate" form, other lateral marginal spines, however, remain more or less same in all these stages; feathered setae on lateral and posterior margins appear in postlarva III and thereafter their number increases with every moult; U almost same in first two postlarval substages, with exopod being longer than endopod; in succeeding moults, endopod increases in size; number of setae on margin of exopod and endopod show progressive increase; A1- basal segment remains always longer than other two segments; in postlarva III, it develops a hollow to accommodate eye; number of setae bordering this depression also increases with every moult; prosartema on inner basal region of segment becomes broader and larger; no appreciable change observed in 2nd and 3rd segments of A1; number of segments in flagella increases with each moult; A2-no great change in antennal scale observed, except for increase in number of setae and thickening of outer region; flagellum

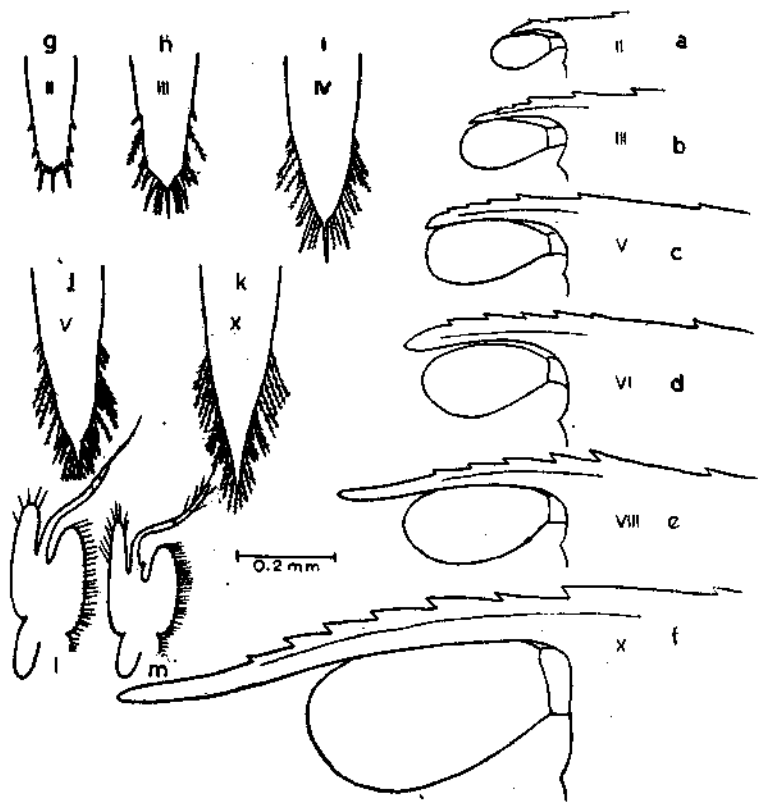

Fig. 5. *Parapenaeopsis stylifera* – a. Rostrum of postlarva I, b. Rostrum of postlarva III, c. Rostrum of postlarva V, d. Rostrum of postlarva VI, e. Rostrum of postlarva VIII, f. Rostrum of postlarva of X, g. Telson of postlarva II, h. Telson of postlarva III, i. Telson of postlarva IV, j. Telson of postlarva V, k. Telson of postlarva X, l. Mxp1 of postlarva V, and m. Mxp1 of postlarva VIII.

becomes longer with the addition of segments at each moult; Md- up to postlarva III, Md remains essentially same as in postlarva I; in postlarva IV, ventral tooth becomes stronger, proximal segment of palp, which was smaller in preceding stage, grows slightly larger, flat and acquires more setae along its margin; by postlarva VIII, Md as in adult; Mx1-peduncular lobes unchanged with distal lobe being larger than proximal; endopod which is unjointed and without seta in postlarva I, becomes broad at base and narrow at tip with a small seta and it remains in that condition until postlarva X; Mx2- endites of Mx2 become more thinner and narrower; endopod appears slightly reduced especially with increase in size of postlarvae; scaphognathite enlarges with every moult, along with also increase in number of marginal setae; Mxp1-remains almost unchanged, each with a peduncle consisting of 2 lobes and unjointed exopod and endopod up to postlarva IV; in next substage (Fig. 5 l), endopod increases in length, becomes slender and tip segmented with terminal segment carrying a long seta; number of setae in exopod also increases; endopod of postlarva VIII (Fig. 5 m) with a curve near middle and develops a pair of spines at base, distal segment of endopod carrying 5 or 6 small setae; number of endopodal segments increase to 4 or 5 in postlarva IX; Mxp2 and Mxp3-no appreciable change during postlarval growth, except curvature formed by distal 3 segments of endopod of Mxp2, which becomes more pronounced in later substages; by gradual increase in size and by development of more setae they attain adult characters; Per-little change in essential characters, each leg with 2-segmented protopod and 5-segmented endopod; Per 1 to 3 chelate; Pleopods-remain uniramous till postlarva VII and acquire a tiny bud-like inner branch devoid of any seta in postlarva VIII; a few setae develop in the next substage and endopods attain almost half size of exopod by postlarva X.

Metapenaeus monoceros (Fabricius)

Mysis I (Fig. 6a): Tl-2.30-2.58 mm; Cl-0.65-0.68 mm.

C-rostrum reaches almost tip of eye or slightly falls short; minute antennal and pterygostomial spines present; A1 (Fig. 6b)-peduncle 3-segmented, proximal segment longest and terminal segment shortest; flagella unjointed, inner branch small and outer longer carrying 5 aesthetes; a conspicuous inner marginal spine on proximal segment; A2 (Fig. 6c)-flagellum unjointed, reaching half of scale and provided with 2 setae at tip; scale with 8 setae along tip and inner margin, and one seta at outer margin just behind outer anterolateral angle; Md (Fig. 6d)-cutting edge formed by a conspicuous ventral tooth followed by a row of 6 to 8 teeth, last 3 or 4 being long, slender and pointed; palp rudimentary; Mx1 (Fig. 6e)-consists of an unsegmented protopod, 3-segmented endopod and a small knob-like exopod; 2 lobes of protopod carry several stout and toothed spines; first segment of endopod bears 3 setae, second 2 setae and terminal segment with 4 long setae; exopod with 4 plumose setae; Mx2 (Fig. 6f)-5 endites, lower-most largest with 5 or 6 long setae; endopod 3-segmented; scaphognathite with 7 setae on its borders; Mxp1 (Fig. 6g)-protopod 2-segmented; endopod 4-segmented with 5 setae on terminal segment; exopod finger-like, half length of endopod and with 4 apical setae; Mxp2 (Fig. 6h) and Mxp3 (Fig. 6i)-protopod 2-segmented; endopod 5-segmented, distal segment carrying 4 setae; exopod unsegmented, about 3/4 endopod; Per (Fig. 6j)-1-3 legs formed by 2-segmented protopod, an unsegmented, indistinctly chelate endopod and an unsegmented exopod; Per 4 and 5 with a protopod of 2 segments, endopod indistinctly segmented at tip and an unsegmented exopod, Ab-5th and 6th segments each with a large, conspicuous dorsomedian spine at posterior border; a small anal

spine on Ab6; U (Fig. 6k)-well developed, endopod with 11-12 setae and without spine; exopod with 12 setae and outer distal spine; T (Fig. 6 l)-posteriorly lobed with 7 spines on each lobe; colouration-antennular peduncle brown; eye stalks with both yellow and brown pigments; ventral side of abdomen with a row of branched brown chromatophores; telson with a patch of brick red pigments.

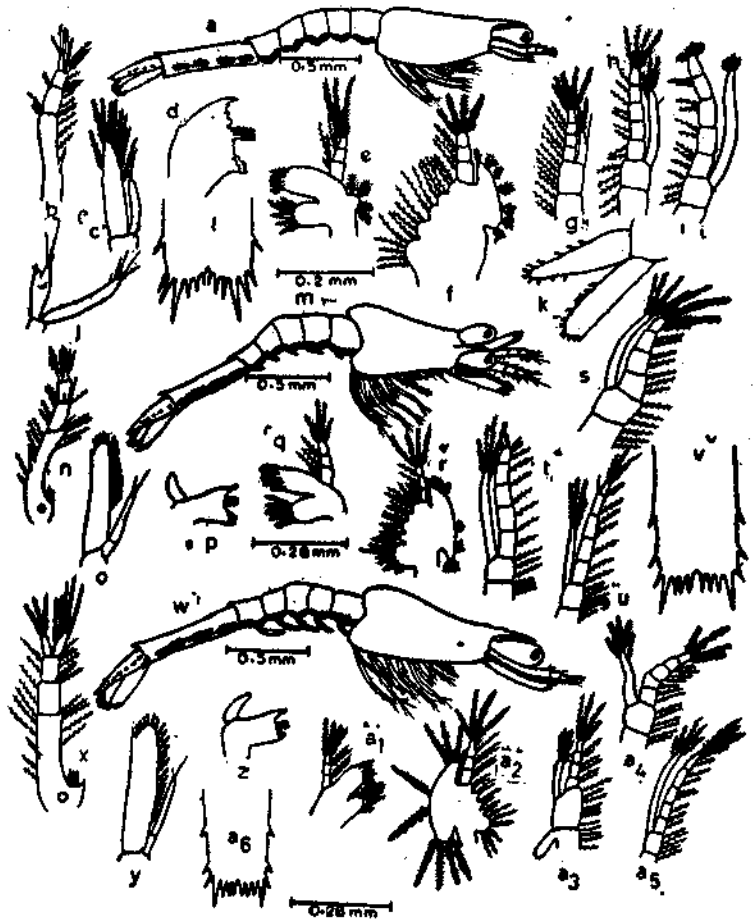

Fig. 6 *Metapenaeus monoceros* – a. Mysis I (side view), b. A1 of same, c. A2 of same, d. Md of same, e. Mx1 of same, f. Mx2 of same, g. Mxp1 of same, h. Mxp2 of same, i. Mxp3 of same, j. First pereopod of same, k Uropod of same, l. Telson of same, m. Mysis II (side view), n. A1 of same, o. A2 of same, p. Md of same. q. Mx1 of same, r Mx2 of same, s. Mxp1 of same, t. Mxp2 of same, u Mxp 3 of same, v. Tip of telson, w. Mysis III (side view), x. A1 of same, y. A2 of same, z. Md of same, a_1. Mx1 of same, a_2. Mx2 of same, a_3. Mxp1 of same, a_4. Mxp2 of same, a_5. Mxp3 of same, and a_6. Tip of telson.

Mysis II (Fig. 6m)- Tl-2.43-3.38 mm; Cl-0.58-0.88 mm.

C-rostrum 3/4 length of eye stalk and possesses a dorsal tooth; antennal and pterygostomial spines present, but hepatic spine absent; A1 (Fig. 6n)-rudiment of stylocerite and a well developed statocyst present on basal segment, 3 small and stumpy setae present above statocyst; flagella unsegmented and almost equal in length; A2 (Fig. 6 o)-flagellum 2-segmented and half as long as scale, which is

provided with 15 or 16 setae and a small anterolateral spine; Md (Fig. 6p)-palp enlarged, but without setae; Mx1 (Fig. 6q)-exopod disappears, other structure same as in previous substage; Mx2 (Fig. 6r)-essentially same as in preceding substage, except for increase in number of setae in scaphognathite to 10; Mxp1 (Fig. 6s), Mxp2 (Fig. 6t) and Mxp3 (Fig. 6u)-no change from mysis I; Per-protopod of Per 1-3, 2-segmented, distal segment being chelate; Ab-spine on 5th and 6th segments similar to that of previous substage; pleopod buds appear as small, knob-like projections; U- a minute tooth develops at posterolateral margin of exopod which bears 13 or 14 setae; endopod with 15 or 16 setae; T (Fig. 6v)-posterior lobes less prominent than in previous substage; colouration-distribution of pigments essentially similar to that of previous substage, but more conspicuous and larva more brownish.

Mysis III (Fig. 6w): T1-2.80-3.4 mm; C1-0.75-0.93 mm.

C-rostrum with 2 dorsal teeth, reaches 3/4 of eye; on each side an antennal, a pterygostomial and a small hepatic spine present; A1 (Fig. 6x)-same as in previous substage; A2 (Fig. 6y)- flagellum slightly more than half length of scale and with a basal segment; scale with 21 setae, anterolateral spine reaching tip of scale; Md (Fig. 6z)-palp increases in size; Mx1 (Fig. $6a_1$)-as in mysis II; Mx2 (Fig. $6a_2$)-scaphognathite with 12 or 13 setae; Mxp1 (Fig. $6a_3$)-same as in previous substage, except for development of a small gill at base of appendage; Mxp2 (Fig. $6a_4$) distal three segments of endopod slightly curved in; Mxp3 (Fig. $6a_5$)-essential characters same as in mysis II; Per- similar to previous substage; Ab-pleopode 2-segmented, but uniramous and non-functional; U-no change except for increase in number of setae; T (Fig. $6a_6$)-posteriorly almost truncate, but still with 7 spines on each half.

Postlarva I: T1.3.30-3.73 mm; C1-1.00-1.10 mm.

Mohamed, Rao and George (1968) have recently described this substage. Diagnostic characters are: rostrum less than half length of eye, with 2 principal and 2 smaller spines; carapace with conspicuous antennal and a smaller hepatic spine; expods of pereopods disappear and endopods modified into walking legs, first 3 pairs of legs chelate 3rd pair being longest; 1st leg with a minute basial and ischial spine; dorsomedian spine present only on Ab. seg. 6; pleopods more developed and bear long terminal setae; telson carries 2 pairs of spines on lateral margin and 5 pairs posteriorly.

Advanced postlarva - A series of postlarvae measuring from 3.30 mm to 11.98 mm in total length are examined (Table 2). Rostrum and C - Rostrum (Fig. 7a to 7h) remains less than half length of eye stalk up to postlarva III, whence it increase in length and by postlarva V it surpasses eye, reaching almost middle of second segment of A1 peduncle by postlarva VII; number of dorsal teeth on rostrum increases gradually and as in *P. stylifera* postlarvae, often a minute spine observed in front of the well developed anterior-most tooth, becoming larger and stronger in the next moult; no appreciable change in carapace, except hepatic and antennal spine become thicker at each moult; Ab-little change in ab. seg. during postlarval growth observed, 6th segment remains longest in all substages, median dorsal spine on this segment becomes smaller at each moult to be represented by a sharp point in postlarva IX; T (Figs. 7i to 7o) and U- in postlarva II, posterior margin of telson with 6 spines, median 2 of which larger, spines on posterolateral corner longest and those on lateral margin smaller; in postlarva III, posterior margin develops a triangular process and the posterior median spines are now placed on the tapering border of this process; in the next substage no great change, except

TABLE 2. *Postlarval substage of* M. monoceros

Substage	Tl mm)	Cl (mm)
I	3.30-3.73	1.00-1.10
II	3.73-3.90	1.05-1.11
III	4.13-5.00	1.13-1 28
IV	5.05-6.38	1.30-1.63
V	6.58-7.28	1.45-1.63
VI	8.50	2.50
VII	8.85 8.88	2.50-2.56
VIII	10.13-10.85	3.00-3.13
IX	11.25-11.98	3.20-3.75

that triangular process becoming conspicuous, observed; in postlarva VII, spines on tapering border disappear and tip of telson ends in an acute spinous process with 2 long subterminal spines, which gradually become smaller in subsequent moult and disappear completely in postlarva IX; lateral spines however still persist, although very small in size; in essential characters, uropod remains almost the same throughout postlarval development, except for increase in size and addition of setae at each moult; A1-in postlarva II, proximal segment which remains longest throughout, develops a small depression in middle to house eye, this depression in subsequent moults deepens and a few setae appear on its border; prosartema observed in postlarva I grows in size with every ecdysis; inner median spine of basal segment disappars in postlarva IV; not much variation in 2nd and 3rd segment of A1 observed; flagella increase in length at each moult, inner flagellum being slightly thinner and longer than outer in earlier substages, but this difference in length decreasing gradually in advanced substages; A2- in postlarva II, flagellum almost as long as scale with 6 segments and in postlarva III, it extends beyond scale and composed of 8 or 9 segments, thereafter increasing in length with addition of segments; scale remains same in all essential characters up to postlarva VI, except for increase in number of marginal setae; a small longitudinal ridge-like thickening appears near outer lateral margin in postlarva VII and this thickening becomes prominent in succeeding substages; Md-in postlarva III, teeth on molar surface become smaller; palp flattend with large distal segment, number of plumose setae on margin also increases; in succeeding substages, main change observed in Md relates chiefly to palp which gradually increases in size; Mxl-endopod, which is small and without setae in postlarva I, further degenerates in postlarva II and disappears in postlarva III; of two lobes of peduncle, distal lobe remains larger throughout; number of setae on inner side increases at each moult; Mx2-3 endites of protopod do not show much change; unjointed endopod of postlarva I gradually decreases in size and in postlarva IX, becomes as long as distal endite of protopod; scaphognathite increases in size and attains characteristic ear-like shape as development advanced, number of setae on margin also increases; Mxpl- in postlarva III, 2 or 3 spine-like projections appear at proximal inner region of endopod; exopod becomes broader and distal margin beset with 4 or 5 setae; no appreciable change in structure observed up to postlarva VI, but in postlarva VII, endopod becomes slender and segmented, the proximal segment being longer and distal carrying 2 small setae; tip of exopod becomes slightly narrow with 6 or 7 setae; in postlarva VIII, endopod further developed, 3-segmented, while exopod slightly reduced in size; Mxp2 and Mxp3-show only little change during postlarval growth; distal 3 segments of Mxp2 get more curved inward and number of setae also increases at every substage; Mxp3 increases in length and with addition of setae gradually attains adult characters; Per-of 3

chelate legs, 3rd continues to the longest; attain most of adult characters in postlarva III, and further change observed only in gradual increase of size at every moult; pleopod remain uniramous with a basal peduncle and a distal segment bearing long plumose setae up to postlarva VII, in postlarva VIII, a small knob-like endopod develops for first time and in next substage, it grows out slightly with a few setae at tip.

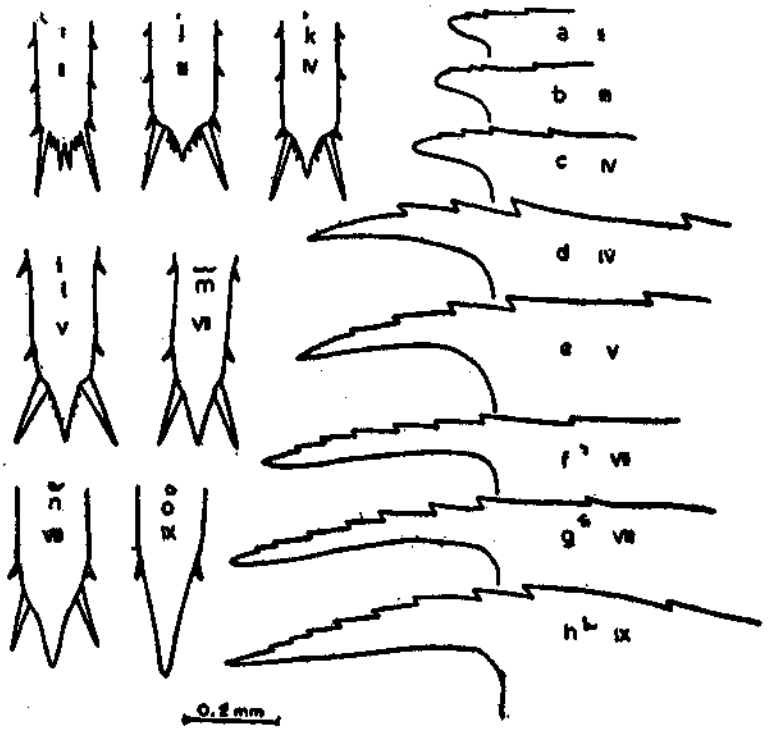

Fig. 7. *Metapenaeus monoceros* – a. Rostrum of postlarva II, b. Rostrum of postlarva III, c. Rostrum of postlarva IV, d. Rostrum of postlarva IV, e. Rostrum of postlarva V, f. Rostrum of postlarva VII, g. Rostrum of postlarva VIII, h. Rostrum of postlarva IX, i. Telson of postlarva II, j. Telson of postlarva III, k. Telson of postlarva IV, l. Telson of postlarva V, m. Telson of postlarva VII, n. Telson of postlarva VIII and o. Telson of postlarva IX.

Metapenaeus affinis (H. Milne-Edwards)

Information on the eggs and larvae of the species is limited to the works of Hudinaga (1935) who described the eggs and nauplial stages. 3 substages of mysis and first postlarva have been obtained from plankton and these are described below:

Mysis I (Fig. 8a): Tl-2.13-2.40 mm; CL-0.55-0.68 mm.

C-rostrum long and pointed, extends to tip of eye or slightly beyond it reaching distal end of first antennular segment; carapace with a small antennal and conspicuous pterygostomial spine; A1 (Fig. 8b)- first segment of peduncle longer than 2nd and 3rd which are equal in length; flagella unsegmented, inner very much smaller; rudiment of stylocerite present; A2 (Fig. 8c)-scale with 8 or 9

setae and without anterolateral spine; flagella unsegmented, with a single terminal setae and a minute one at subterminal outer margin; Md (Fig. 8d)-with a conspicuous ventral spine and 6 or 7 serrated teeth; no palp; Mx1 (Fig. 8e)- 2 endites with stout setae; endopod 3-segmented, first 2 segments with 2 setae each and 3rd with 3 terminal setae; exopod small, knob-like, and bears 4 plumose setae; Mx2 (Fig 8f)-5 endites proximally, lower-most largest; endopod 4-segmented; exopod with 5 setae along its border; Mxp1 (Fig. 8g)-protopod 2-segmented, carrying long setae on the inner margin; endopod 5-segmented and exopod unsegmented; Mxp2 (Fig. 8h) and Mxp3-portopod 2-segmented; endopod

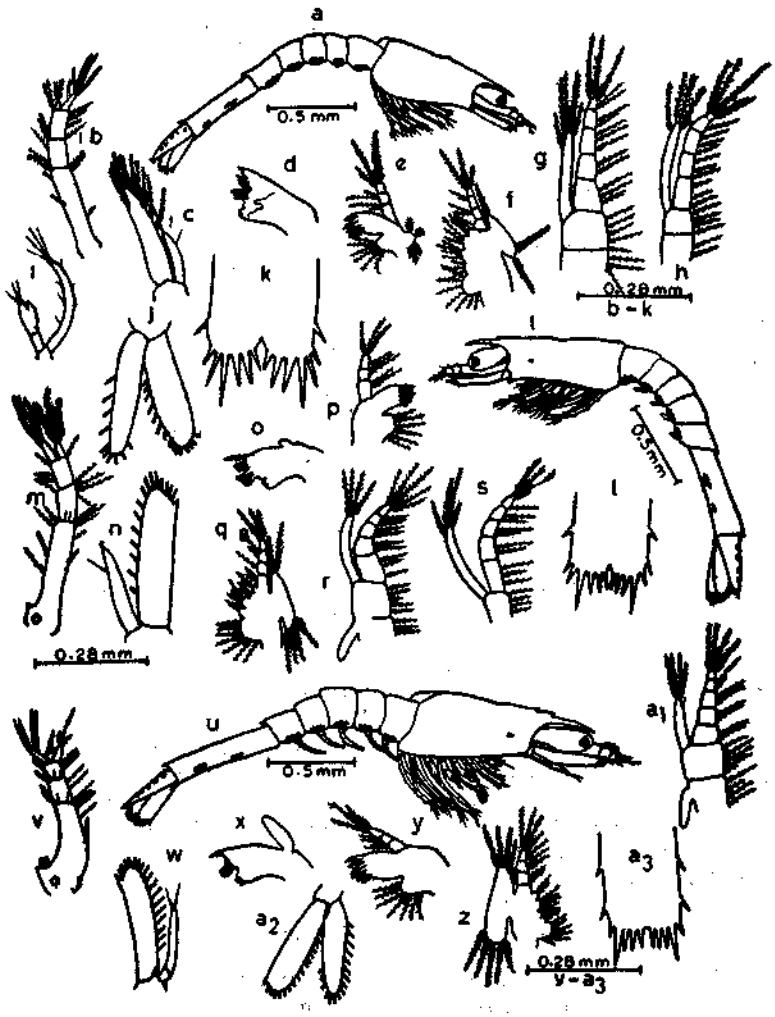

Fig. 8. *Metapenaeus affinis* – a. Mysis I (side view), b. A1 of same, c. A2 of same, d. Md of same, e. Mx1 of same, f. Mx2 of same, g Mxp1 of same, h. Mxp2 of same, i. First pereopod of same, j. Uropod of same, k. Tip of telson of same, l. Mysis II (side view), m. A1 of same, n. A2 of same, o. Md of same, p. Mx1 of same. q. Mx2 of same, r. Mxp1 of same, s. Mxp2 of same, t. Tip of telson of same, u. Mysis III (side view), v. A1 of same, w. A2 of same, x. Md of same, y. Mx1 of same, z. Mx2 of same, a_1. Mxp1 of same, a_2. Uropod of same, and a_3. Tip of telson of same.

5-segmented, terminal segment carrying 4 setae; exopod about 3/4 of endopod; Per (Fig. 8i)-1-3 legs chelate; exopods well developed and each carries a few marginal and 4 terminal setae; Ab-5th and 6th segments possess posterior median dorsal spine; 6th segment longest and with an anal spine; U (Fig. 8j)-well developed, exopod with 14 or 15 setae, while endopod with only 10 setae; T (Fig. 8k)-posterior margin with a deep median cleft; 7 spines on each lobe, 4th from outer lateral longest; colouration-live larvae slightly brownish; eye stalk a little yellowish; ventral side of abdomen provided with branched brownish chromatophores; dorsal portion of telson with brownish pigments.

Mysis II (Fig. 8 l) : Tl-2.38-2.90 mm; Cl-0.55-0.78 mm.

C-rostrum develops a small dorsal tooth; antennal, pterygostomial and a minute hepatic spine present; A1 (Fig. 8m)- peduncle 3-segmented with a developing statocyst and stylocerite at base of first segment; flagella unsegmented, inner slightly shorter than the outer; A2 (Fig. 8n)-scale with an anterolateral spine on outer margin and 15 setae along inner margin and tip; flagellum unsegmented and about half length of scale; Md (Fig 8o)- spine on ventral side strong and tooth-like; out of 6 or 7 serrated teeth, posterior 3 longer and slender; a small bud-like palp present; Mx1 (Fig. 8p)- similar to that of previous substage, except for absence of exopod; Mx2 (Fig. 8q)-setae scaphognathite increase to 9; Mxp1 (Fig. 8r), Mxp2 (Fig. 8s) and Mxp3- Mxp1 develops small gill at basal region of protopod; other charac ters similar to those of previous substage; Per-endopod of 1-3 legs 3 segmented, distal segment being chelate; Ab-pleopod develop on segment 1-5, uniramous, unsegmented, small and non-functional; U- well developed, endopod and exopod with 12 and 15 setae respectively; T (Fig. 8t)-spination same as in previous substage; median cleft of posterior margin shallow.

Mysis III (Fig. 8u): Tl-2.88-3.28 mm; Cl-0.75-0.79 mm.

C-rostrum reaching tip of eye and with 2 dorsal teeth; carapace with same spines as in mysis II, but the hepatic spine larger; A1 (Fig. 8v)-essentially same as in mysis II; 3 stout setae present over statocyst; A2 (Fig. 8w)-flagellum 2-segmented, basal segment short, tip carries 2 short setae; scale with 16 or 17 setae and outer anterolateral spine almost reaches tip of scale: Md (Fig. 8x)-only 3 serrated teeth; palp well developed; morphological structures of Mx1 (Fig. 8y), Mx2 (Fig. 8z), Mxp 1-3 and pereopods essentially similar to those of preceding substage, except for increased number of setae in scaphognathite of Mx2 and size of Mxp and per.; Ab- pleopods increase in size, segmented, but small without setae and non-functional; U (Fig. $8a_2$)-exopod develops a small spine at distal outer margin and beset with 16 setae; endopod with 15 or 16 setae; T (Fig. $8a_3$)-7+7 spines; median cleft of posterior margin disappears.

Postlarva I - Tl-3.85-3.95 mm; Cl-1.16-1.17 mm.

This substage has been described by Mohamed, Rao and George (1968). Rostrum short, projecting a little beyond frontal border of carapace, with 2 longer and 2 smaller spines and a minute epigastric; carapace with well developed antennel and hepatic spine; mouth parts do not show appreciable change from those of mysis III; pereopods without exopods and 1-3 chelate; pleopods well developed, uniramous, 3-segmented, distal segment with setae: median dorsal spine on 5th ab. seg. disappears and that of 6th persists; telson bears 2 pairs of lateral and 5 pairs of posterior spines.

Metapenaeus dobsoni (Miers)

Eggs and the larval stages from nauplius to postlarvae are represented in the present collection. Menon (1951) described nauplius, protozoea and mysis stages, each having 3 substages and 13 postlarval stages. A closer study of naupli obtained by rearing eggs as well as from plankton revealed 2 more substages recognisable between the substages I and II described by Menon (1951). Thus 5 substages are now recognised in the nauplius stage and the substages II and III described by Menon (1951) are redesignated here as substages IV and V respectively.

Egg: viable eggs shperical, translucent, measure 0.32-0.44 mm in diameter, embryonic mass 0.24-0.26 mm in diameter.

Nauplius I: T1-0.26-0.28 mm; Gbw-0.22 mm.

Nauplius II (Fig. 9a): T1-0.30-0.31 mm; Gbw-0.13 mm.

Major differences between Nauplius I and II are in setation of A2, number of furcal spines and shape of posterior region of body. A1-uniramous, unsegmented, with 2 long and one short terminal setae and 2 shorter subterminal setae; A2-biramous, unsegmented, endopod with 2 long and one short terminal and 2 subterminal setae; exopod with 2 long and one short terminal and 4 ventrolateral setae; longer setae of exopod and endopod plumose; Md-biramous, rami short and each ramus carrying 3 setae terminally; posterior part of body elongated and caudal end slightly notched medially differentiating furcal processes; each process bears 4 spines, 2nd from inner-most being longest.

Nauplius III (Fig. 9b): T1-0.32-0.33 mm; Gbw-0.12-0.13 mm.

Appendages show signs of segmentation for first time; furcal lobes developed with a moderately deep notch in between, each lobe bears 5 spines, 2nd from inner-most being longest; A1-proximal portion shows traces of segmentation; an additional lateral setae towards base; A2-endopod with same number of setae as in preceding substage; exopod with 4 terminal and 4 ventrolateral setae, all plumose; Md-same as in previous substage.

Nauplius IV: T1-0.33-0.35 mm; Gbw-0.14-0.15 mm.

Posterior end of body elongates further and number of furcal spines increases to 6 on each lobe; rudiments of Mx1, Mx2, Mxp1 and Mxp2 make their appearance; setation of appendages remains same as in previous substage.

Nauplius V: T1-0.36-0.39 mm; Gbw-0.18 mm.

Major differences between this and preceding substage are seen in development of masticatory portion of mandible, further elongation of posterior region of body and an increase in number of setae of appendages; each furcal lobe generally with 6 spines, but in some specimens an additional minute spine present on inner margin of each lobe; frontal organs present at anterior end of body.

Protozoea I: T1-0.65-0.75 mm; C1-0.25-0.30 mm.

Protozoea II: T1-1.00-1.18 mm; C1-0.37-0.40 mm.

Protozoea III: T1-1.55-1.85 mm; C1-0.45-0.53 mm.

The various morphological features of these substages agree with those described by Menon (1951).

Mysis I (Fig. 9c): Tl-2.12-2.32 mm; Cl-0.60-0.63 mm.

Menon (1951) described mysis I substage of *M. dobsoni* as having 8+8 spines in the telson and a well developed median dorsal spine on the posterior

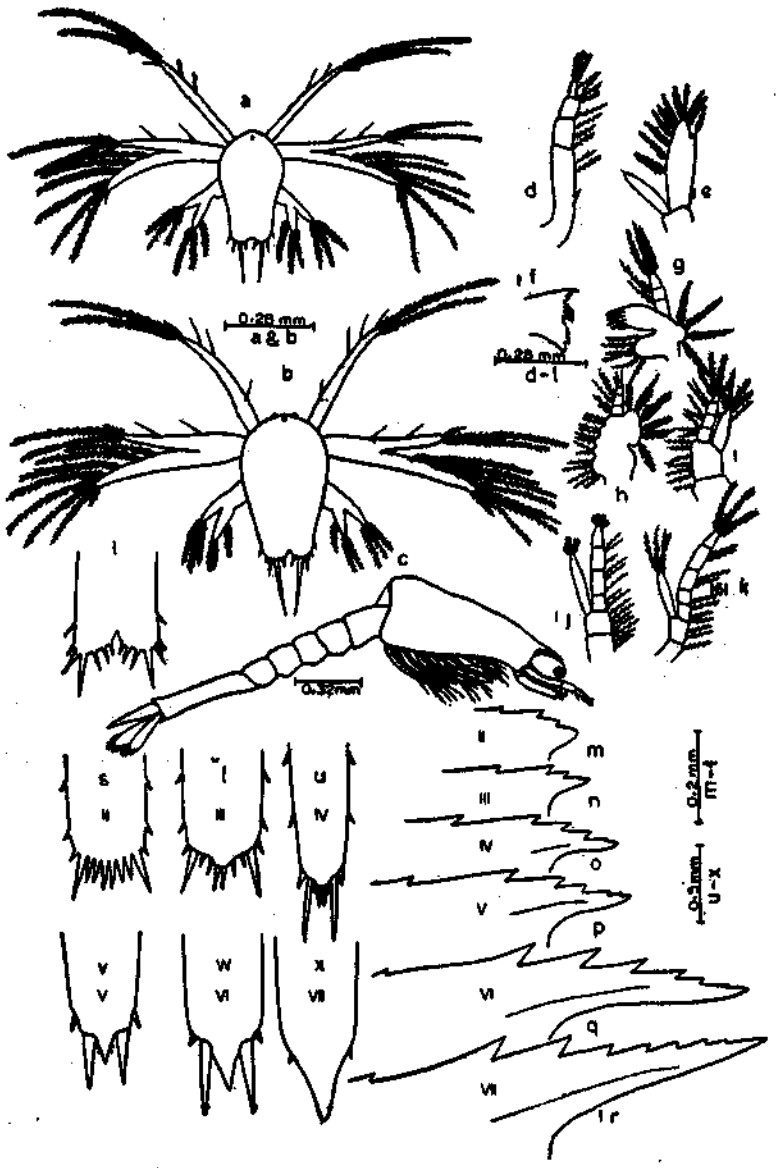

Fig. 9. *Metapenaeus dobsoni* – a. Nauplius II (dorsal view), b. Nauplius III (dorsal view), c. Mysis I (side view), d. A1 of same, e. A2 of same, f. Md of same, g. Mx1 of same, h. Mx2 of same, i. Mxp1 of same, j. Mxp2 of same k. Mxp3 of same, l. Tip of telson of same, m. Rostrum of postlarva II, n. Rostrum of postlarva III, o. Rostrum of postlarva IV, p. Rostrum of postlarva V, q. Rostrum of postlarva VI, r. Rostrum of postlarva VII, s. Telson of postlarva II, t. Telson of postlarva III, u. Telson of postlarva IV, v. Telson of postlarva V, w. Telson of postlarva VI, and x. Telson of postlarva VII.

margin of fifth abdominal segment. During the present investigation, protozoea III of *M. dobsoni* were reared in the laboratory and the mysis I obtained had 7+7 spines in the telson. A few batches of larvae were reared and in all cases 7+7 telson spines in mysis I were only encountered. A comparison of various characters of corresponding substage larvae of different species revealed that the presence of 8+8 spines in the telson as well as a spine on the 5th abdominal segment are characteristic of mysis I of *Parapenaeopsis stylifera*, which also occur with the same stage of *M. dobsoni* in the inshore waters. Moreover, both protozoea III and mysis II of *M. dobsoni* possess only 7+7 spines in the telson as observed by Menon (1951) and also in the present study. Hence, mysis I substage, as reported by Menon (1951) should be considered as that of *P. stylifera* and not of *M. dobsoni*. Detailed description of this substage based on the present material is given below:

C- rostrum without tooth, reaches 3/4 of eye; antennal and pterygostomial spine present; A1 (Fig. 9d)- peduncle 3-segmented, first segment longest, with a prominent spine on inner side; 2nd segment slightly longer than 3rd which carries 2 unsegmented subequal flagella, inner flagellum being short and knob-like; A2 (Fig. 9e)-scale with 11 setae, 8 along inner margin and extremity and 3 along outer distal margin; flagellum unjointed, half as long as scale, tip carrying a single short setae; Md (Fig. 9f)- cutting edge with 3 long, slender and serrated tooth, incisor region with a conspicuous tooth; molar region with 7 or 9 small and short teeth; Mx1 (Fig. 9g) 2 endites, each with a number of short setae; endopod 3-segmented and exopod knob-like with 4 plumose setae; Mx2 (Fig. 9h)- protopod with 5 endites, proximal endite with 5 setae and rest with 2 or 3 setae; endopod 4-segmented, distal segment carries 3 terminal setae exopod well developed with 5 or 6 plumose setae; Mxp 1 (Fig. 9i)- protopod possesses many setae at inner margin; endopod 4-segmented, distal segment carrying 4 apical setae; exopod about 3/4 of endopod and with 4 terminal setae; Mxp2 (Fig. 9j)-almost similar to that of Mxp1; Mxp3 (Fig. 9k)-consists of a protopod of 2 segments, 5-segmented endopod and a small unsegmented exopod; lateral and terminal setae present on endopod; Per-well developed, 1-3 chelate, each composed of 2-segmented protopod and endopod and an unjointed exopod; endopods of 4-5 legs unjointed; Ab-median dorsal spine present only on posterior margin of 6th segment; U-protopod with a small curved outer spine; exopod broad with 10 setae, endopod narrow with 6 or 7 setae; T (Fig. 9 l)-posterior margin deeply cleft medially, each lobe with 7 spines, 4th spine from outer side being longest.

Mysis II: Tl-2.24-2.55 mm; Cl-0.65-0.70 mm.

Material on hand agress with the description of this substage given by Menon (1951). Development of pleopod buds on 1-5 ab. seg., presence of a single dorsal tooth on rostrum, enlargement of endopods pereopods are the main differences noticed from previous substage.

Mysis III: Tl-2.55-2.98 mm; Cl-0.73-0.75 mm.

Substage characterised by presence of 2 dorsal spines on rostrum, and uniramous, segmented, but non-functional pleopods on ab. seg. 1-5; A1, A2, Md; Mx1, Mx2 and Mxp 1-3 almost remain unchanged from preceding substage, pereopods further develop, first 3 being chelate; telson bears 2 pairs of lateral and 10 posterior spines; median cleft on posterior margin reduced considerably.

Postlarva I: Tl-3.05-3.15 mm; Cl-0.75-0.80 mm.

Material on hand agrees in all essential characters with description of same substage given by Menon (1951) and Mohamed, Rao and George (1968).

Exopods of pereopods lost; uniramous pleopods acquire setae and become functional; a conspicuous hepatic spine present on carapace; posterior margin of telson almost truncate with 7+7 spines.

Advanced postlarvae: In the present study, a series of postlarvae measuring from 3.00 to 18.88 mm were examined (Table 3). Since it has not been possible to follow the postlarval development moult by moult, different substages have been distinguished mainly by the increase in the number of spines on the rostrum. Menon (1951) described 13 postlarval substages reared in the laboratory during a period of approximately 7 weeks. He observed the sequence of changes taken place in the rostrum, pleopods and telson during the course of postlarval growth. Additional observations made at present are given below.

TABLE 3. *Postlarval substages of* M. dobsoni

Substage	TI (mm)	CI (mm)	No. of spines on the rostrum
I	3.00–3.50	0.93–0.97	3
II	3.56–3.62	1.03–1.07	3
III	4.56–5.55	1.12–1.25	4
IV	6.32–8.58	1.75–1.80	5
V	9.68–12.00	2.13–2.50	6
VI	13.50–14.00	3.05–3.28	7
VII	17.98–18.88	4.00–4.25	8

Rostrum in postlarval substages I and II short (Fig. 9m), not extending beyond base of eye; in postlarva IV (Fig. 9 o) rostrum reaching one fourth and in postlarva V and VI three fourth of eye; dorsoventral width of base of rostrum conspicuous, basal crest differentiating from postlarva V onwards; biramous condition of pleopod develops first in specimens measuring about 8.50 mm (postlarva IV); the changes undergone in telson are shown in Figs. 9s to 9x; in postlarva III, median region of posterior border protrudes out as a small process carrying two inner-most median spines of earlier substage, other spines placed on tapering margin, there being 2 pairs of smaller and a pair of larger and longer spines (Fig. 9t); in postlarva IV, median process further develops and becomes prominent and smaller spines on tapering margin become minute; these spines disappear in next substage when tip of telson appears 'tridentate' with a conspicuous posteromedian process and a pair of spines on either side of it; as the development proceeds, latter spines gradually get reduced in size and in postlarva VII they disappear completely.

Penaeus indicus H. Milne-Edwards

Two protozoeal, three mysis and seven postlarval substages are described here from the present collections.

In most of the characters, protozoea II agrees with the description given by Menon (1937) for the same substage.

Protozoea III has a body length varying from 2.55 mm to 2.70 mm. Although, the morphological features of the various appendages agree with that of Menon's (1951) description, the telson bears 8 spines on each lobe and thus differs from protozoea II which possess only 7 spines on each lobe.

Mysis I (Fig. 10a) : T1-2.60-3.75 mm; C1-0.70-1.05 mm.

C-rostrum pointed, extending to 3/4 eye, often having a minute spine at base; supraorbital, antennal and pterygostomial spines, which are more conspicuous in smaller specimens measuring up to 2.6 mm present; minute hepatic spine detectable under higher magnification; A1 (Fig. 10b)- peduncle 3-segmented, basal segment longest, rudiment of stylocerite present at base of first segment which has also an inner lateral spine; 2nd segment with 2 or 3 setae on inner margin; 3rd segment with 2 flagella at tip, outer flagellum one third longer than inner, unsegmented, slightly constricted at middle and terminally bears 5 aesthetes; inner flagellum with 2 setae at tip and 2 aesthetes at base; many setae present at joints of A1; A2 (Fig. 10c)- protopod 2-segmented, flagellum shorter, about 2/3 length of scale and unsegmented; scale with 14 or 15 setae and a subterminal spine at anterolateral margin; Md (Fig. 10d)-ventral side of cutting edge with 2 larger and 1 small teeth, followed by 6 or 7 slender teeth with lateral spinules; palp rudimentary; Mx1 (Fig. 10e)- protopod bilobed carrying stout setae at inner margin; endopod 3-segmented, first 2 segments with two setae each, 3rd with 3 apical setae; Mx2 (Fig. 10f)-scaphognathite with 11 setae; endopod 4-segmented; protopod 5 lobed, proximal largest and provided with 6 or 7 setae; Mxp1 (Fig. 10g)-protopod 2-segmented; endopod 4-segmented carrying long setae; exopod unsegmented and bears 4 terminal setae; Mxp2 (Fig. 10h)-endopod 4-segmented and beset with long setae at tip, inner and outer margins; exopod unsegmented; Mxp3 (Fig. 10i)-endopod 5-segmented, terminal segment with 4 setae; exopod unsegmented, about 3/4 of endopod and tipped with 5 or 6 setae; Per-1 -3 chelate, posteriorly increasing in length, each (Fig. 10j) composed of 2-segmented protopod and endopod, and an unsegmented exopod, in some specimens, faint segmentation of exopod seen at tip; chela with 2 or 3 terminal hairs; exopod with 6 setae; Ab-segment 4 to 6 possess a dorsomedian spine on posterior margin, that of 5th and 6th being larger and conspicuous; 6th segment longest and bears a small posteroventral spine; U-protopod with a curved ventral spine; exopod lamallar and elongated, with 16 or 17 setae on margin, a small spine also present at outer terminal boarder; endopod bears 13 setae on outer border; T (Fig. 10k)-well developed; posterior margin with a median notch; each lobe with 8 spines, 4th from outer-most being longest.

Mysis II (Fig. 10 l): T1-3.23-4.23 mm; C1-0.80-1.13 mm.

C- rostrum pointed, slightly shorter than eye stalk and a single dorsal spine; supraorbital, antennal and hepatic spines present; pterygostomial spine disappears; A1 (Fig. 10m)-peduncle 3-segmented, with well developed statocyst and a small stylocerite at base; flagella unsegmented, outer longer and with 4 aesthetes and 3 plumose setae along inner margin; inner smaller with 2 subequal setae terminally; A2 (Fig. 10n)- protopod 2-segmented; endopod unsegmented, rod-like, reaching half antennal scale which has 22 setae, 13 along inner margin, 4 on tip and 5 in between tip and subterminal spine on outer margin; Md (Fig. 10 o)-palp well developed, unsegmented; teeth on cutting edge as in previous substage; Mx1 (Fig. 10p)-same as in mysis I; Mx2 (Fig. 10q)-setae on scaphognathite increase to 22 or 25; Mxp1 (Fig. 10r)-exopod presents a small constriction near tip; gill rudiment appears at base of appendage; Mxp2 (Fig. 10s) and Mxp3 (Fig. 10t)-same as in previous substage, except that endopod of Mxp2 5-segmented; Per-1-3 chelate and 4-5 non chelate, first shortest and 3rd longest; each chelate leg composed of 2-segmented protopod, 5-segmented endopod and exopod, proximal segment of latter very long setae long and plumose; Ab-dorsomedian spines present only on 5th and 6th segments, that on 4th disappears; pleopods uniramous and non-functional; U (Fig. 10u)-except for

increase in number of setae to 19 or 20 in exopod and 17 or 18 in endopod, no appreciable change observed; T (Fig. 10v)-posterior margin of telson more or less truncate, each half continues to carry 8 spines.

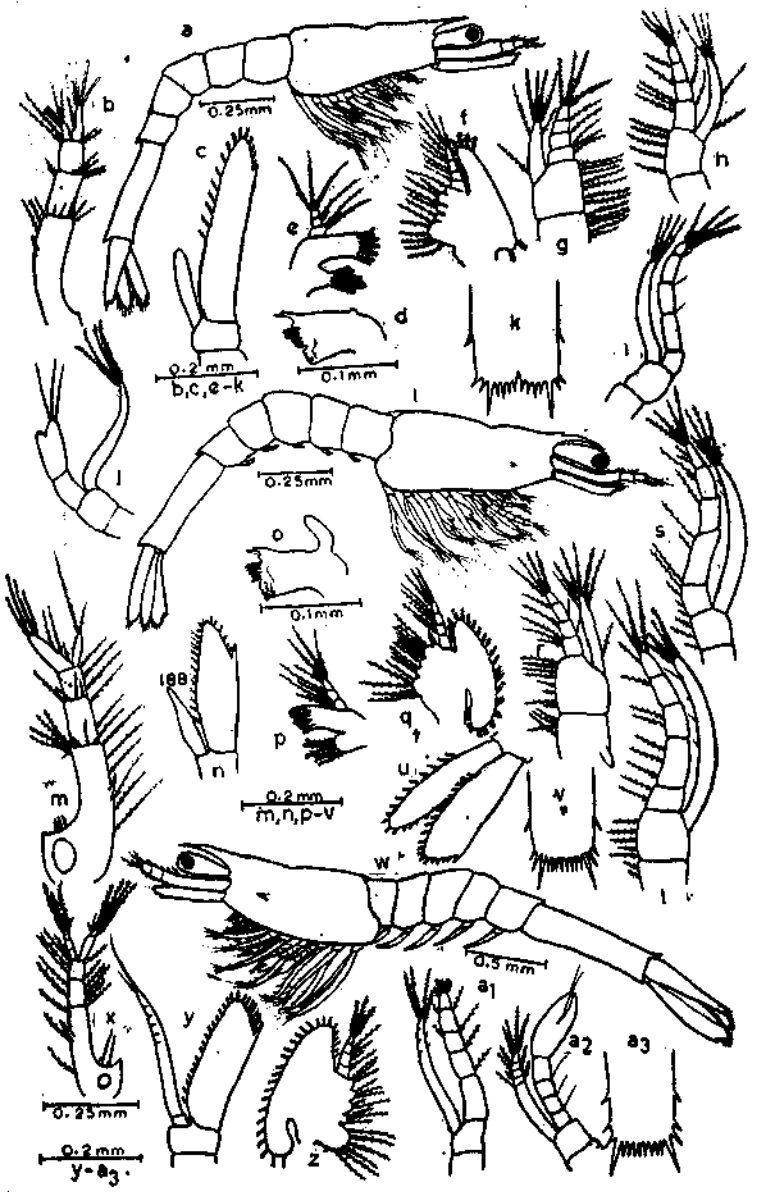

Fig. 10. *Penaeus indicus* – a. Mysis I (side view), b. A1 of same, c. A2 of same, d. Md of same, e. Mx1 of same, f. Mx2 of same, g. Mxp1 of same, h. Mxp2 of same, i. Mxp3 of same, j. First pereopod of same, k. Tip of telson of same, l. Mysis II (side view), m. A1 of same, n. A2 of same, o. Md of same, p. Mx1 of same, q Mx2 of same, r. Mxp1 of same, s. Mxp2 of same, t. Mxp 3 of same, u. Uropod of same, v. Tip of telson of same, w. Mysis III (side view), x. A1 of same, y. A2 of same, z. Mx2 of same, a_1. Mxp3 of same, a_2. First pereopod of same, and a_3. Tip of telson.

Mysis III (Fig. 10w): Tl-4.23-4.50 mm; Cl-1.05 mm.

C-rostrum extending to slightly beyond eyes and with a dorsal tooth and an epigastric spine: supraorbital and antennal spines small; hepatic spine well developed; A1 (Fig. 10x)-peduncle 3-segmented, carrying a conspicuous statocyst at base; inner branch of flgellum 3-segmented; outer flagellum 2-segmented, but segmentation indistinct; A2 (Fig. 10y)-flagellum segmented. 4-5 segments at tip indistinct; a pair of subequal apical setae on flagellum present; scale with 26 or 27 plumose setae. anterolateral spine well developed, but not reaching tip; Md-same as in mysis II; palp not segmented; Mx1- same as in previous substage; Mx2 (Fig. 10z)-protopod with 5 endites; endopod 4-segmented and with 3 setae at tip; scaphognathite with 26 or 27 setae; Mxp1 and Mxp 2-same as in mysis II; Mxp3 (Fig. $10a_1$)-endopod 5-segmented, exopod terminally 3-segmented, segments indistinct; Per (Fig. $10a_2$)-same as in previous substage; endopods of last 2 pairs possess 5 segments; Ab-dorsomedian spines on 5th and 6th segments; pleopods conspicuous, each 2-segmented, without setae and non-functional; U-exopod and endopod with 28 and 24 setae respectively; spine on outer distal end of exopod prominent; T (Fig. $10a_3$)-changes only a little, truncate with 8+8 spines.

Postlarva I: Tl-5.23-5.95 mm; Cl-1.28-1.35 mm.

A detailed description of postlarva I obtained from the plankton collections is given by Mohamed, Rao and George (1968). Rostrum bears a single dorsal spine and an epigastric spine lying on dorsal carina slightly in advance of hepatic spine; a small supraorbital spine present on anterior margin of carapace, anterolateral angle of carapace devoid of any spine; A1 and A2 well developed; Mx1-2 and Mxp1-3 do not show any appreciable change from those of preceding substage; Per-1-3 chelate, 3rd pair being longest; pleopods uniramous, first three pairs well developed and longer than the last two pairs; spination of ab. seg. same as in mysis III; telson bears 3 pairs of lateral and 5 pairs of posterior spines.

Advanced postlarvae:

A series of specimens measuring from 5.23 mm to 13.75 mm, have been distinguished as 7 postlarval substages based on the number of rostral spines as shown in Table 4.

TABLE 4. *Postlarval substage of* P indicus

Substage	Tl (mm)	Cl (mm)	Number of spines on the rostrum	
			Dorsal	Ventral
I	5.23–5.95	1.20–1.35	2	0
II	6.13–7.18	1.38–1.48	2	0
III	7.05–8.10	1.50–1.75	3	0
IV	8.05–9.33	1.63–1.75	4	0
V	9 25–10 23	1 75–1.88	5	3
VI	10.85–11.25	1.88–1.95	6	5
VII	13 75	2.89	7	6

C and rostrum (Fig. 11a to 11f)- The important changes observed in the carapace are in the size of the hepatic spine and the rostrum; hepatic spine small in postlarva I and II, but becomes larger with each moult; in postlarva III, rostrum with 3 dorsal spines and extends just beyond eye; in succeeding moults,

it increases in length and in postlarva V reaches tip of proximal segment A1 and develops three minute ventral spines (Fig. 11d); in postlarva VI, rostrum surpasses tip of proximal segment of A1 and in the next substage grows very much beyond it; Ab-in postlarva III, median dorsal spine on 6th segment disappears; as in other species, this segment remains always the longest; T (Figs. 11g to 11k) and U-up to postlarva III substage telson remains the same as in postlarva I; in postlarva IV, posterior margin tapers slightly and setae develop in between the spines of the lateral margins; as the larva passes VIth substage, a small triangular projection develops medially on the posterior border with the median spines placed on either side of the tapering border of this projection; during further development, this projection enlarges and the spines on either side of this projection disappear and tip of telson becomes narrow with large posterolateral spines placed at base of median projection; margin of telson beset with a number of long, plumose setae: no appreciable change occurs in the structure of the uropod, though the size and the number of setae increase with every moult; A1-in postlarva II, proximal segment gets hollowed out in

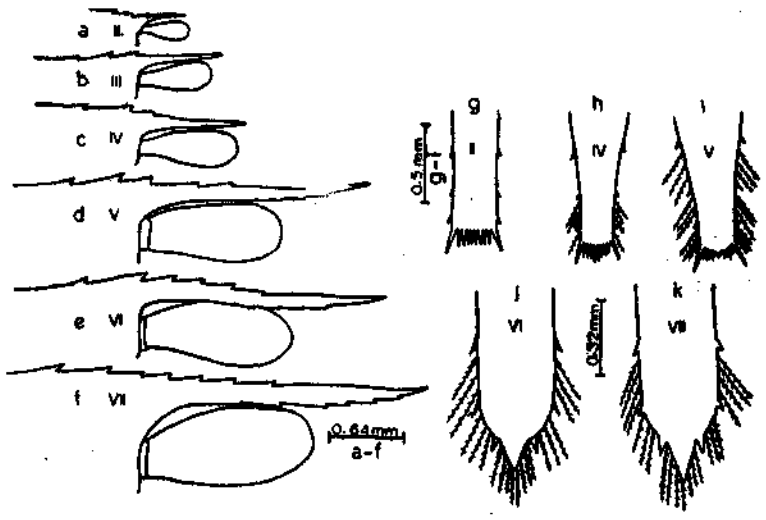

Fig. 11. *Penaeus indicus* – a. Rostrum of postlarva II, b. Rostrum of postlarva III, c. Rostrum of postlarva IV, d. Rostrum of postlarva V, e. Rostrum of postlarva VI, f. Rostrum of postlarva VII, g. Telson of postlarva II, h. Telson of postlarva IV, i. Telson of postlarva V, j. Telson of postlarva VI, and k. Telson of postlarva VII.

middle to accommodate eye and borders of this hollow develop setae; prosartema also grows on inner side; 2nd and 3rd segments of A1 almost remain the same throughout the postlarval growth, but the number of segments in the flagella increases with every moult; A2-scale remains narrow and long in early postlarvae, but gradually becomes broader and shorter with every moult; flagellum which is shorter than scale in postlarva I and II becomes as long as scale in postlarva III and consists of 6 segments; in postlarva V, 8-segmented and longer than scale, while in postlarva VII flagellum consists of many segments and very much longer than scale; Md-in postlarva I, teeth on cutting edge reduced both in size and number, in postlarva II, points of the teeth can only be seen and in the subsequent substages, they considerably decrease in size and in postlarva VII, the cutting edge becomes almost smooth with very minute points; palp which has only a few setae in postlarva I, increases in size and the

whole outer border becomes setose by the time it reaches postlarva VII; Mx1 and Mx2-very little change observed in the structure of Mx1; scaphognathite of Mx2 becomes larger and more setose, while the endites get reduced in size as the development advances; Mxp1 and Mxp2- protopod of Mxp1 remains almost the same throughout, but endopod which is smaller in postlarva I and II, begins to increase in size from postlarva VI, becoming slender and tip slightly curved outward; in Mxp2, rudimentary exopod of early postlarvae, attains larger size in postlarva VII; Mxp3-in essential characters, this appendage remains unchanged, but the size and number of setae increase with every moult; Per-each chelate leg consists of a 2-segmented protopod and a 5-segmented endopod, the last 2 segments forming the chela; 4th and 5th legs similar in shape, each 7-segmented and non-chelate, the 5th one being larger than the 4th.

COMPARISON OF EGGS AND LARVAE

All the known penaeid eggs are spherical with the exception of *Penaeus kerathurus* (as *P. trisulcatus*) (Heldt, 1938) and characterised by the presence of wide perivitelline space which render than much lighter and bouyant. A comparison of the size of eggs of different species of penaeid prawns show that the eggs of the species dealt with here are relatively larger in size than most of the species studied elsewhere. The largest egg so far recorded belongs to *P. indicus* (0 45-0.47 mm diameter), followed by those of *P. stylifera* (0.40-0.43 mm) and *M. dobsoni* (0.32-0.41 mm).

Nauplii of penaeids are simple in structure and have a typical pyriform body. The number of nauplial substage in the development of penaeids has been found to vary with the species. Although the maximum number of substages recorded is 8 in species such as *P. kerathurus*, *Scicyonia carinata* (Heldt, 1938) and *Metapenaeus bennetae* (Muriel and Bennett, 1951), in most of the species there are only 5 substages. Among the Indian penaeids, the nauplii of three species are known. Menon (1951) described only three substages in *M. dobsoni*, but the present study indicate that 5 substages can easily be distinguished in this species also. Subramanyam (1965) reported 3 nauplius substages in *P. indicus*. However, a comparison of these substages with those described for allied species points to the possibility that some more substages, exist, as the difference in size and number of furcal setae between the substages are great. The nauplii of *P. indicus*, *M. dobsoni* and *P. stylifera* exhibit differences in the setation of the appendages, especially in the second naupliar appendage (antenna). Another interesting difference is the presence of frontal organs in Nauplius V substage of *M. dobsoni*, while they are absent in *P. indicus* and *P. stylifera*.

In protozoea, 3 substages are found in all the penaeids so far studied. The protozoea of *P. stylifera* can easily be separated from that of *M. dobsoni* and *P. indicus* by the nature of telson lobes which are slightly elongated and characteristic of the species. Absence of supraorbital spine is also an important feature by which it differs from the corresponding stages of these species. Protozoea III substage of *P. indicus* and *P. stylifera* are similar in having 8 pairs of spines in the telson, while in *M. dobsoni* there are only 7 pairs and this number remains unchanged throught the substages.

Considerable variation in the number of substages in mysis has also been recorded, the maximum number being 14 in *Parapenaeus longirostris* and the minimum 2 in *Trachypenaeus constrictus* (Heldt, 1938). In most of the species there are only 3 substages. This variation in the number may be due to the

influence of the environment in which the larvae develop as pointed out by Pike and Williamson (1964) and Cook and Murphy (1965); or the quantity of food available to the larvae (Broad, 1957). All the five species studied at present show 3 substages in the mysis stage. The mysis larvae of *P. indicus* and *P. stylifera* are similar in telsonic armature, but the former can easily be separated from the latter by its size, presence of supraorbital spine in the carapace and the nature of antennal scale. The mysis of the three species of *Metapenaeus* differ from each other in length of rostrum, spination of 5th abdominal segment and colouration. In *M. dobsoni*, the dorsal median spine on 5th abdominal segment is absent, while in the other two species it is very conspicuous. Mysis larvae of *M. monoceros* appear brownish due to the presence of dense chromatophores on the ventral side of abdomen. In *M. affinis*, the chromatophores are fewer in number and much less conspicuous, while the mysis larvae of *M. dobsoni* are generally whitish and only a single branched chromatophore is present on the ventral side of each abdominal segment.

A comparison of the various characters of the first postlarvae of all these species has been made by Mohamed, Rao and George (1968). The first postlarvae of the three species of *Metapenaeus* show close resemblances in many characters. However, they could be distinguished from each other by the distribution of chromatophores and number of spines on the rostrum. The first postlarva of *P. stylifera* is clearly different from those of the other species. The size of this larvae is larger than those of the species of *Metapenaeus*, but slightly smaller than that of *P. indicus* which is the largest among these. Number of segments on the inner branch of the distal segment of the antennular peduncle, number of segments on the flagellum of the antenna, setation of the mandibular palp and the number of spines in the telson are some of the characters in which *P. stylifera* differs from the other species.

Based on the above studies, keys for the identification of mysis and first postlarval stages of these prawns are given below:

A KEY FOR THE IDENTIFICATION OF MYSIS STAGE OF FIVE COMMERCIAL PENAEID PRAWNS OF INDIA

1. Telson with 8 + 8 spines.....2

   Telson with 7 + 7 spines.....3

2. Supraorbital spine present.....*Penaeus indicus*

   Supraorbital spine absent.....*Parapenaeopsis stylifera*

3. Median dorsal spine on 5th abdominal segment conspicuous.....4

   Median dorsal spine on 5th abdominal segment absent.....
   .....*Metapenaeus dobsoni*

4. Rostrum extending to 3/4 eye; larvae conspicuously brownish.....
   .....*Metapenaeus monoceros*

   Rostrum reaching tip of eye or slightly beyond it; larvae not brownish
   .....*Metapenaeus affinis*

A KEY FOR THE IDENTIFICATION OF FIRST POSTLARVAE OF FIVE COMMERCIAL PENAEID PRAWNS OF IND A
(revised from Mohamed, Rao and George, 1968)

1. Telson with 7+7 spines.....2

   Telson with more than 7+7 spines.....4

2. Rostrum with 4 spines (2 large and 2 small); long setae on distal lateral aspect of 6th abdominal segment.....3

   Rostrum with 2 spines; no setae on distal lateral aspect of 6th abdominal segment.....*Metapenaeus dobsoni*

3. Epigastric spine on carapace absent; larva brownish.....
   .....*Metapenaeus monoceros*

   Epigastric spine on carapace present; larva not brownish.....
   .....*Metapenaeus affinis*

4. Telson truncate, with 8+8 spines, median posterior spines equal; median dorsal spine present on 5th and 6th abdominal segments.....
   .....*Penaeus indicus*

   Telson tapering between posterolateral spines, with 8+1+8 spines, median posterior spine very much longer than adjacent spines; median dorsal spine on abdominal segments absent.....*Parapenaeopsis stylifera*

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DISCUSSION

P. S. GORE: Wanted to add to the information given by Mr Vedavyasa Rao on the larval development of *Metapenaeus affinis* that Dr M. R. Ranade, Research Officer, Marine Biological Research Station, Ratnagiri has been able to get all the naupliar and protozoeal stages of *M. affinis* in the laboratory (This work is being published).

K. J. MATHEW: Are the variations found in the Mysis stage been reported from other geographical regions?

P. VEDAVYASA RAO: No. Although in the normal pattern of development of penaeid prawns 3 substages are observed, in some species variations in the number of stages are noticed.