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COASTAL AQUACULTURE:

MARINE PRAWN CULTURE

Part I

LARVAL DEVELOPMENT OF INDIAN PENAEID PRAWNS

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
P. B. No. 1912, Cochin 682 018, India

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Bulletins are issued periodically by Central Marine Fisheries Research Institute to interpret current knowledge in the various fields of research on marine fisheries and allied subjects in India.

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CONTENTS

PREFACE

The present trend of exploitation of many of the conventional marine capture fisheries indicates that they would be, in the near future, reaching the maximum sustainable yield. This situation warrants an immediate consideration of rational management of the exploited resources and means of stepping up of production to meet the ever increasing demand. The latter could be achieved by two ways — by harvesting the non-conventional resources such as the krill, the mesopelagic fishes and so on, where a beginning has already been made, or by intensifying the aquaculture practices of suitable organisms. Although man took to aquaculture well over 2000 years ago, research support for its development came forth only recently. This is especially so in sea farming and aquaculture in the estuaries, brackishwater areas, coastal inundated stretches, saline lagoons and mangrove ecosystems, broadly termed here as coastal aquaculture.

Some of the Asian countries have been practising aquaculture in coastal and contiguous brackish waters as traditional subsistance fisheries since ancient times. However, the stagnation during the past few years in the total marine fish production of the world despite the increasing demand for protein food played a major role in creating a global awareness of the importance of aquaculture and its intensive practice. At present, about 6 million tonnes out of about 73 million tonnes of world fish production is realised through aquaculture.

In India, inland aquaculture production has not been estimated precisely, but the inland fish production, excluding that from the brackish waters, is assessed to be around .0.7 million tonnes. The coastal brackishwater areas, which in extent cover over 2 million hectares in the country, are only marginally used for aquaculture in Kerala and West Bengal. The present yield from this source is of the order of 25,000 tonnes of finfishes and prawns. The potentials in this sector are, however, immense and are now well recognised at the state and national levels of planning and development. The coastal aquaculture and its blending with capture fisheries, or in combination with other avocation in agriculture and animal husbandry offers great opportunities for an integrated rural development of the coastal areas.

The Central Marine Fisheries Research Institute has from the mid-seventies given priority for building up research infrastructure for the development of coastal aquaculture. The techno-economic feasibility studies on culturing finfishes, prawns, lobsters, crabs, mussels, oysters, pearl culture, seaweed culture and culture of other ancillary resources have revealed the possibilities of their commercial scale operations as monoculture or polyculture. The technology of culture of live food organisms is also being evolved parallely, and intensive efforts are underway to develop suitable compounded feed. While these developments are progressing, the transfer of technology to technical personnel as well as to fish farmers is undertaken simultaneously through intensive field programmes.

In retrospect, a significant breakthrough made by the Institute in this field has been in the breeding and culture of marine prawns (Penaeidae) of the country. An ad hoc proejct on the "Culture and Propagation of Marine Prawns" sponsored by the Indian Council of Agricultural Research, in January 1974, enabled setting up of a Field Laboratory and farms at Narakkal, near Cochin, through the continuing efforts of Shri K.H. Mohamed, Senior Scientist of the Institute. Within a short period of three years, it has been possible to breed under controlled conditions the economically important penaeid prawns occurring along the southwest coast of India in this Laboratory and successfully culture them to harvestable sizes in 3 to 4 months after stocking.

Providing the necessary research inputs, investigations on hatchery production of prawn and finfish seed, brood stock development, production of live and compounded food for various stages of development of prawns and fishes, fish and shellfish pathology and on intensive mono- and polyculture of finfishes and shellifishes are being actively pursued at the Narakkal Laboratory and other Research Centres of the Institute. It is proposed to publish the results of the investigations carried out by the Institute on different culture systems in a series entitled "Coastal Aquaculture." The first one in this series is on "Marine Prawn Culture" which consists of two parts. Part I on "Larval Development of Penaeid Prawns of India" is presented in this Number of CMFRI Bullettin. Part II deals with the "Culture of marine prawns" Results of investigations on sea farming of mussels, oysters, pearl culture seaweed culture, cage and pen culture of finfishes, lobster culture and culture of other ancillary resources will follow. It is hoped that this publication will stimulate more intensive work on R & D in coastal aquaculture through institutional, regional and national efforts.

E.G.SILAS
Director
C. M. F. R. I

I

Larval Development — Introduction

E. G. Silas

The recent success achieved by the Central Marine Fisheries Research Institute in the artificial propagation of penaeid prawns has yielded a very interesting "spin off" in the form of authentic descriptions and illustrations of the larval stages of 8 commercially important species of penaeid prawns reared from eggs spawned in the laboratory. The complete larval development, from egg to the postlarva of *Penaeus monodon. P. indicus, Metapenaeus dobsoni, M. affinis, M. monoceros* and *Parapenaeopsis stylifera,* was studied in detail at the Narakkal Prawn Culture Laboratory of CMFRI and that of *Penaeus semisulcatus* at the Kovalam Field Laboratory of the CMFRI Madras Research Centre. At the Kakinada Research Centre of the CMFRI the larval development of *Metapenaeus brevicornis* was traced up to the mysis I stage. These studies have brought to light a wealth of information on the detailed structure and sequence of development of the setation pattern of the larval appendages. Some of the earlier descriptions of the larvae of Indian penaeid prawns were based on material collected from the plankton; either the series was incomplete or the identity of the species was uncertain. Even the more recent larval publications based on laboratory culture of penaeid prawns in India suffer from inadequacies in description and inaccuracies in illustrations.

In chapters II to IX of this Bulletin the detailed structure and setation of the appendages of 8 species of Indian penaeid prawns belonging to 3 genera are described and illustrated. It is followed by a chapter on the general pattern of larval development with a discussion on the generic similarities and specific differences. A guide to the identification of the brackishwater phase of the postlarvae of commercially important Indian penaeid prawns is also given in the end.

The procedure followed for rearing the larvae was more or less similar for all the species. The mature females were collected from the sea and kept in filtered seawater in 50 litre plastic basins and aerated with a compressor. Spawning took place in the night between 11. p.m. and 2 a.m. and the nauplii hatched out during the succeeding day. No food was needed during the nauplius stage. As soon as they became protozoea they were fed with phytoplankton consisting mainly of *Thalassiosira* sp. collected from the ponds or pure cultures of *Thalassiosira* sp. or *Tetraselmis* sp. When the larvae reached the mysis I stage, freshly hatched *Artemia* nauplii were added every day along with the phytoplankton till they became postlarvae.

The developing larvae from the culture tanks were preserved in 10% buffered formalin at frequent intervals, to get the complete series of larval stages. Camera lucida sketches were made of freshly killed larvae so that no details were lost.

Total length of nauplius was measured between the anterior and caudal ends excluding furcal setae; width of the body was taken at the point of greatest width. Total length of protozoea, mysis and postlarva was taken from the tip of rostrum to the end of telson excluding the setae and the carapace length was taken including the rostrum. The measurements were taken with an ocular micrometer.

As the embryonic development is more or less similar in all the 8 species studied, it is described only in the case of *Penaeus indicus*. The larval descriptions are very brief; only the changes in structure and setation observed in each substage are given. Importance has been given to the figures which have been drawn with great care, so as to depict even the relative length of the setae on the appendages correctly. The setation of the appendages has been checked thoroughly by examining a number of specimens of each larval stage to ensure that no setae have been overlooked or wrongly drawn. The setules on the plumose setae are not shown to avoid cluttering the figures. The exopods of the maxillipeds and pereopods usually lie on the sides on the slides prepared for drawing and hence the lateral setae of these exopods are drawn only on one side in most of the figures.

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

MTL: Mean total length; MCL: Mean carapace length; MW: Mean width; MFS: Mean length of longest pair of furcal setae; A1: Antennule; A2: Antenna; Md: Mandible; Mx1: Maxillule; Mx2: Maxilla; Mxp1: First maxilliped; Mxp2: Second maxilliped; Mxp3: Third maxilliped; P1: First pereopod; P2: Second pereopod; P3; Third pereopod; P4: Fourth pereopod; P5: Fifth pereopod.

II

Larval development — *PENAEUS MONODON* FABRICIUS

E. G. Silas
M. S. Muthu
N. N. Pillai
K. V. George

Penaeus monodon, the giant tiger prawn, has spawned in the Narakkal Prawn Culture Laboratory of the CMFRI and larvae have been reared to the juvenile stage. At a rearing temperature of 26.5°C to 28.5°C the nauplii hatched out of the eggs 16-17 hours after spawning; the nauplius stage lasted 40-55 hours; the duration of protozoea stage was 4½-6 days and the mysis stage lasted for 3-6 days. The larva passed through 6 nauplius, 3 protozoea and 3 mysis substages before becoming postlarva 1. The detailed structure of the larval substages is described and illustrated in this paper.

Penaeus monodon, the giant tiger prawn spawned in the Prawn Culture Laboratory at Narakkal and the larvae were reared up to juvenile stage. Although the larval history of this species has been studied by Villaluz et. al. (1969, *Philippine J. Sci.*, 98 (3-4): 205-233[1]) at Philippines, the figures are not clear enough to show the details of setation. The object of this paper is to illustrate and describe in detail the morphological characters of the larval stages of this most important species of penaeid prawn, so that they can be readily compared with the other species of *Penaeus* already described. The rearing temperature was 26.5°c to 28.5°c and the salinity of the water 30.2‰- 33.5‰.

DESCRIPTION OF DEVELOPMENTAL STAGES

EGGS

The eggs (Fig. 1.a) are small with a narrow perivitelline space. The egg diameter varied from 0.25 to 0.27 mm and the yolk mass 0.22 to 0.24 mm. The radiating jelly like substance seen in the case of *P. indicus* is also present in the freshly laid eggs of this species. The developing nauplius almost fills up the entire space inside the egg. The eggs hatched out 16-17 hours after spawning.

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NAUPLIUS I

MTL: 0·31 mm (0.29-0.32 mm); MW: 0.17 mm (0.17-0.18 mm); MFS: 0.12mm (0.10-0.13mm):

Furcal setae 1+1; minute posterodorsal tooth present; all setae non-plumose; A1 with 2 inner lateral setae distal one longer than proximal, 2 long setae and 1 minute setal rudiment terminally and 1 long seta on outer distal margin; A2 exopod bears 5 long setae along inner and distal margin, endopod with 2 short inner lateral setae and 2 long setae and a minute setal rudiment terminally; Md with 3 long distal setae on exo and endopods (Fig. 1. b). Duration of this substage was 3-4 hours.

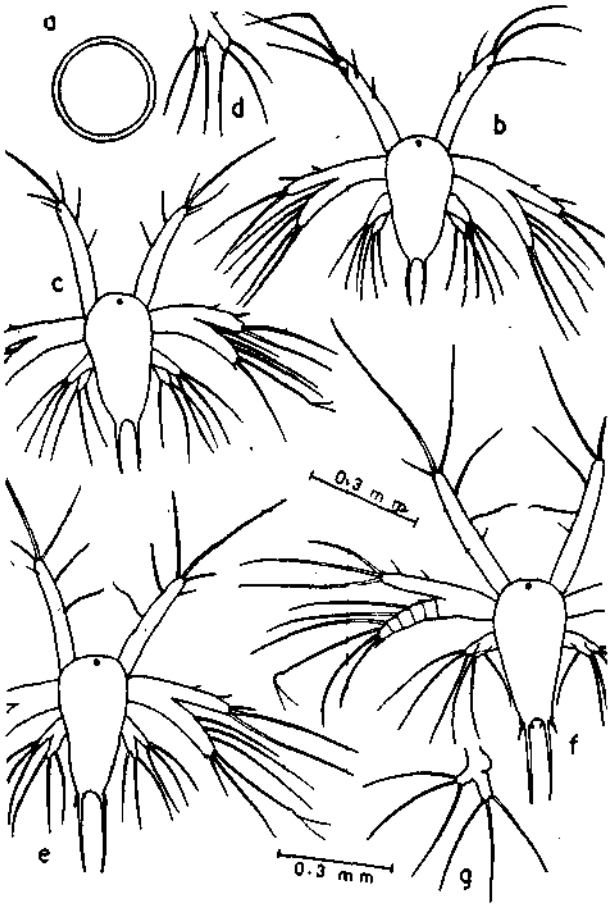

Fig. 1 *Penaeus monodon:* a - egg; b - nauplius I; c - nauplius II; d - Md of nauplius II; e - nauplius III; f - nauplius IV; g - Md of nauplius IV

NAUPLIUS II

MTL: 0.32mm (0.31-0.32mm); MW: 0.17mm (0.17-0.18mm); MFS: 0.14mm.

Furcal setae 1+1; posterodorsal tooth absent; setae plumose; outer terminal and outer lateral setae of A1 shorter than in previous stage, setal rudiment has become a short seta; a setal rudiment added to distal outer angle of A2 exopod, the 4th seta from proximal end bifurcate distal to characteristic bend, this particular seta remains bifurcate in all subsequent nauplius substages (Fig. 1, c,d). Duration of this substage was 3-4 hours.

NAUPLIUS III

MTL: 0.33mm (0.31-0.34 mm); MW: 0.17mm (0.17-0.18mm); MFS:0.18mm (0.17-0. 20mm).

Furcal setae 3+3 (Fig.1,e); inner terminal setae of A1 longer than outer terminal seta, outer lateral seta very thin and short, a minute seta added proximal to 2 existing inner lateral setae, A2 exopod with 6 plumose setae and a setal rudiment, in endopod setal rudiment has grown into a short non-plumose seta. Duration of this substage was 4-5 hours.

NAUPLIUS IV

MTL: 0.36 mm (0.34-0.36 mm); MW: 0.19 mm (0.18-0.21mm); MFS: 0.20mm (0.18-0.21mm).

Furcal setae 4+4 (Fig.1,f), frontal organs seen, outer distolateral seta of A1 lost, inner terminal seta longer; A2 exopod with faint segmentation, setal rudiment has become a short seta and another setal rudiment added terminally, a minute seta also added proximally on inner margin, in endopod inner terminal seta longer and plumose and another setal rudiment added terminally; base of Md swollen (Fig. 1,g). Duration of this substage was 5-6 hours.

NAUPLIUS V

MTL: 0.39 mm (0.36 - 0.41 mm);MW:0.18mm; MFS: 0.25 mm (0.22 - 0.25 mm).

Furcal setae 6+6; A1 with minute seta added on outer lateral margin opposite to origin of long distal inner lateral seta, faint segmentation seen in proximal half; A2 exopod with outermost seta longer but still non-plumose (Fig.2,a). Duration of this substage was 10-12 hours.

NAUPLIUS VI

MTL: 0.49 mm (0·46-0.53 mm); MW: 0.20 mm (0.18 - 0.20 mm); MFS: 0.30 mm (0.28 - 0.32 mm).

Furcal setae 7+7 (Fig.2, b), frontal organ prominent, carapace rudiment seen, 2 short setae added to outer distal margin of A1, these 2 setae and the short terminal seta appear to be aesthaetes, the middle one equidistant from other 2; A2 exopod with proximal setal rudiment of previous stage longer, another setal rudiment added proximal to it, a setal rudiment added on outer margin

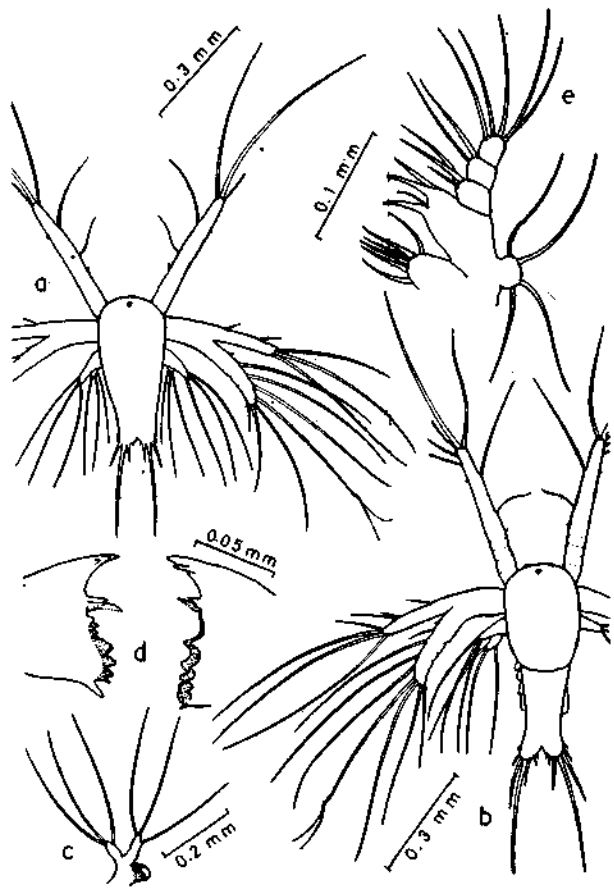

Fig. 2 *Penaeus monodon:* a - nauplius V; b - nauplius VI; c - Md of nauplius VI; Protozoea I; d - Md; e - Mx1

proximally, endopod with 4 terminal setae, 3 long and one short, a short seta added to base of distal inner lateral seta which has become longer; Md with basal swelling very prominent, cutting blade of Md seen inside cuticle, exopod and endopod empty (Fig.2,c). Duration of this substage was 15-24 hours.

PROTOZOEA I

MTL: 1.06 mm (1.05 - 1.09 mm); MCL 0.47 mm (0.44 - 0.49 mm).

Frontal organs rounded; telson (Fig.3,a) with 7+7 setae, outermost pair dorsally disposed, 3rd pair from inner margin of furcal lobes characteristically sigmoid, furcal lobes broad and short with semicircular space between them.

A1 (Fig.3,a) with 3 main segments, proximal one subdivided into 5 subsegments, basal segment with 1 short inner seta, middle segment with 1 long and 1 medium inner lateral setae and 1 short outer lateral seta, distal segment terminally with 2 long setae, 1 short seta and 3 aesthaetes, 1 of which appears to be subterminal; A2 (Fig.3,a) with 9-10 segmented exopod bearing 11 setae along inner and distal margin and 2 short setae on outer margin, endopod 2 segmented, distal segment with 5 terminal setae, one of which is short, proximal segment has 3 inner lateral setae, 2 distal, 1 in middle and 1 at junction of endopod with protopod; Md (Fig.2,d) almost symmetrical with 1 free standing tooth between incisor and molar processes; Mx1 (Fig.2,e) protopod with 2 endites, distal with 1 slender and 3 stout setae and proximal with 6 setae, exopod with 4 feathery setae, endopod 3 segmented, distal segment with 5 long terminal setae, middle with 2 long setae and basal with 3 setae, 2 long and 1 short; Mx2 (Fig.3,b) protopod with 5 endites; basal endite with 6 setae and others with 3-4 setae, exopod with 5 feathery setae, endopod with 4 indistinct segments, distal with 3 long setae and rest with 2 lateral setae each; Mxp1 (Fig.3,c) protopod with 2 indistinct segments bearing numerous setae, endopod 4 segmented, 1st with 3 setae, 2nd with 1, 3rd with 2 and 4th with 5 setae, exopod unsegmented with 7 plumose setae; Mxp2 (Fig.3,d) protopod with 2 indistinct segments bearing 7 inner lateral setae, endopod indistinctly divided into 4 segments, 1st segment with 2 setae, 2nd with 1,

3rd with 2 setae and 4th with 5 setae, exopod with 6 setae; Mxp3 absent. Duration of this substage was 36-48 hours.

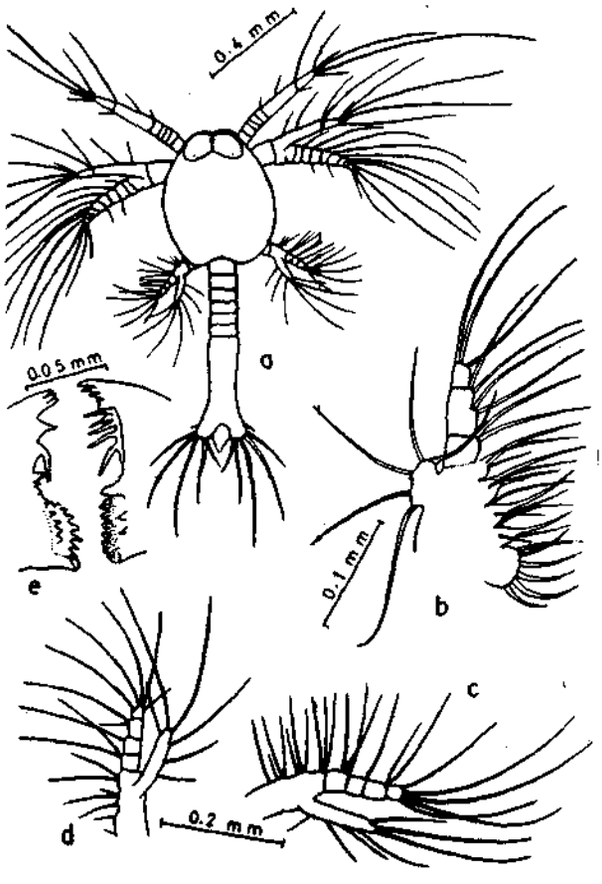

Fig. 3 *Penaeus monodon:* Protozoea I; a - dorsal view; b - Mx2; c - Mxp1 d - Mxp2; protozoea II; e - Md.

PROTOZOEA II

MCL: 0.72 mm (0.70-0.77 mm); MTL: 1.06 mm (1.65-1.68 mm).

Carapace (Fig.4,a) with long ventrally bent rostrum and bifid supraorbital spines, telson with 7 pairs of furcal setae; A1 (Fig.4,a), one hair like seta added to middle segment on outer margin; A2 (Fig.4, a) setae have become longer; Md (Fig.3,c) asymmetrical, left with 5 free standing teeth and right with 1 free standing tooth, molar surface of right Md appears to have a concavity with the rim produced into a number of crenulate teeth, molar surface of left Md not concave but covered with number of toothed ridges and appears to fit into the concavity on right Md; Mx1 (Fig.4,c) distal endite with 7 setae; no change in Mxp1 and Mxp2; Mxp3 absent. Duration of this substage was 36-48 hours.

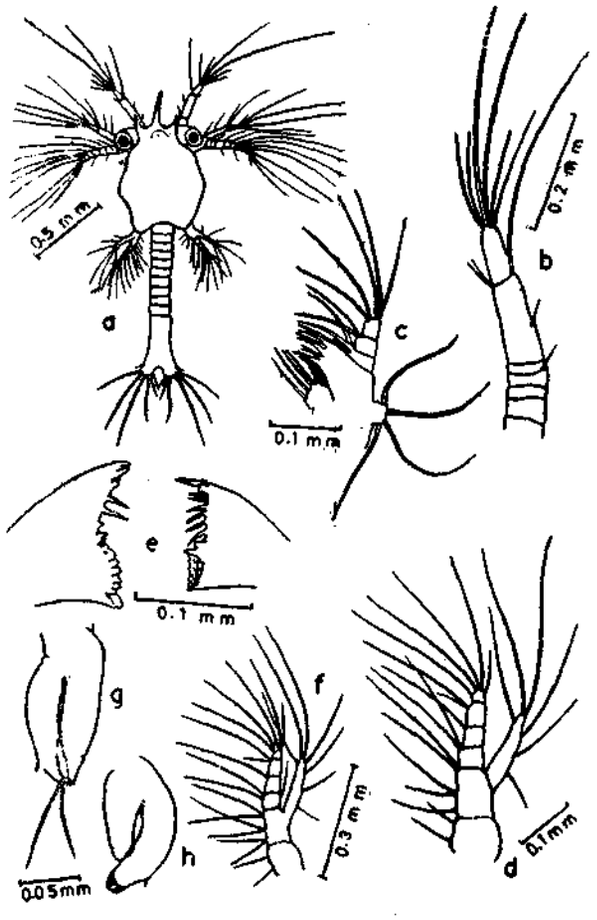

Fig. 4 *Penaeus monodon:* Protozoea II; a - dorsal view; b - A1; c - Mx1; d - Mxp1; Protozoea III: e - Md; f - Mxp2; g - Mxp3; h - bud of P.

PROTOZOEA III

MCL: 0.79 mm (0.70-0.84 mm); MTL: 2.28 mm(2.14-2.38 mm).

Rostrum long, supraorbital simple, not bifid (Fig.5,a); abdominal segments (Fig.5,a) 1 to 5 with dorsomedian spine, 5th and 6th segments with posterolateral spines, 6th also has a pair of ventrolateral spines; biramous buds of Mxp3 (Fig.4,g) and P1 to P5 (Fig.4,h) present; uropods (Fig.5,c) present, exopod tipped with 6 setae and endopod with 2 setae; telson with 8 pairs of furcal setae.

A1 with 5 subsegments of basal segment fused into one unit; no change in A2; Md (Fig.

4,e) right Md with 2 and left with 6 free standing teeth; Mx1.(Fig.5,b)distal endite with 10 setae and proximal with 7 setae; Mx2(Fig. 5,c), more setae added to endites; Mxp1 (Fig.5,d) one inner lateral seta added to 2nd segment of endopod, expood with 2 additional setae; Mxp2 (Fig.4,f), an outer lateral seta added to 1st segment of endopod, 1 more seta added to exopod; Mxp3 developed,

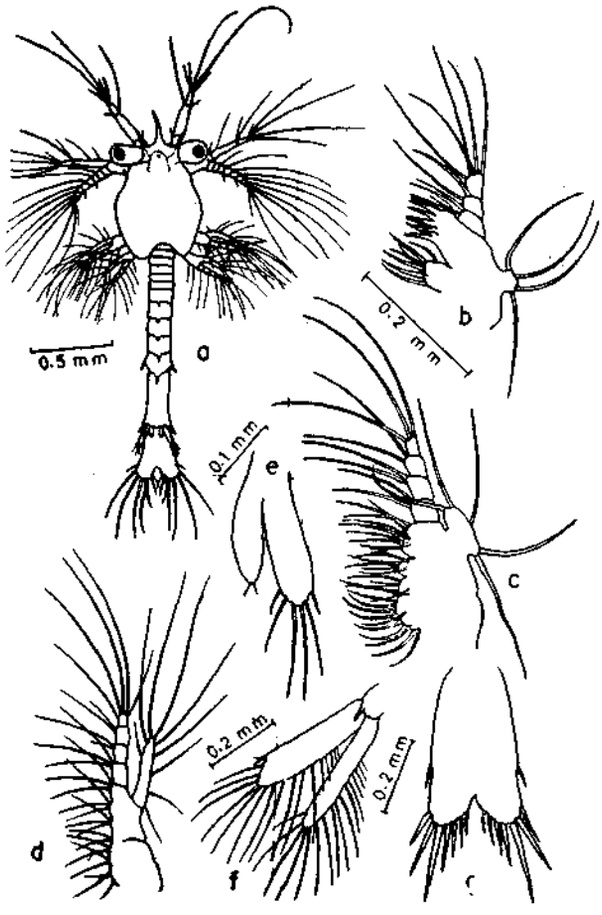

Fig. 5 *Penaeus monodon:* Protozoea III: a - dorsal view; - Mx1; c - Mx2; d - Mxp1; e - uropod. Mysis I: f - uropod; g - telson.

as biramous bud (Fig.4,g), endopod rudiment with 2-3 setae. Duration of this substage was 36-48 hours.

MYSIS I

MCL: 1.18 mm (1.14-1.23 mm); MTL: 3.79 mm (3.65 - 3.96 mm).

Carapace (Fig.6,a) with rostrum longer than eye, no rostral tooth, supraorbital, pterygostomial and hepatic spines present; abdominal segments 3-6 with dorsomedian spines, 5th and 6th with prominent posterolateral spines, 6th with prominent posteroventral spines also, curved ventromedian spine present at junction of 6th abdominal segment with telson, minute pleopod buds on abdominal segments; telson (Fig.5,g) with 8+8 short stout setae, cleft deep reaching halfway between level of origin of 2 pairs of outer lateral setae.

A1 (Fig.6,b) 3 segmented, basal segment with anteromedian ventral spine, 2 setae above stylocerite rudiment, outer flagellum with 5

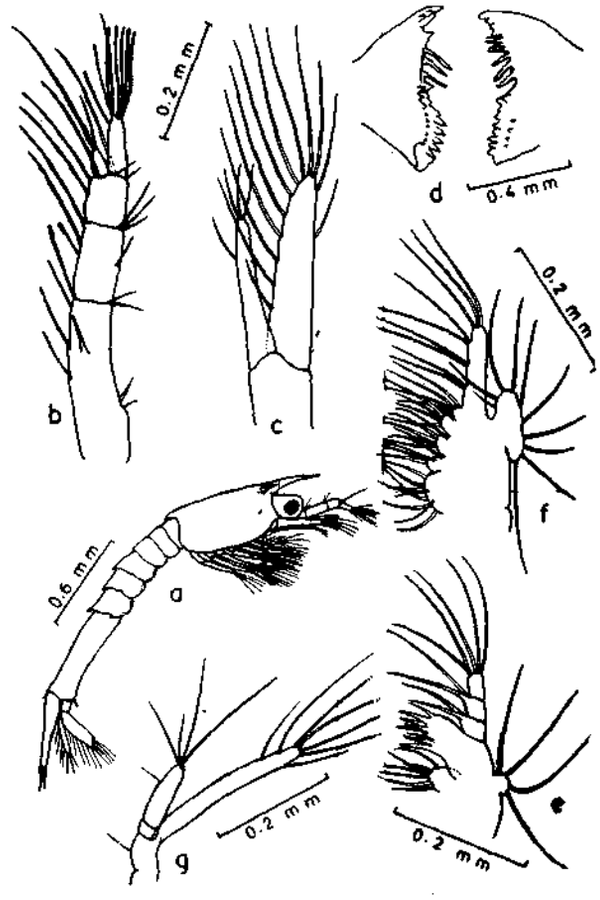

Fig. 6 *Penaeus monodon* Mysis I: a - lateral view; b - A1; c - A2; d - Md; e - Mx1; f - Mx2; g - P3

aesthaetes and 3 setae, inner flagellum minute with 2 setae, 1 long and 1 short; A2 (Fig.6,c), exopod unsegmented, fringed with 11 setae on inner and distal margin, and a plumose outer distolateral seta, endopod tipped with 3 short setae; Md (Fig.6,d), right with 3 and left with 7 free standing teeth, palp not seen; Mx1

(Fig.6,e) exopod retained; Mx2 (Fig.6,f) 10 setae on exopod; Mxp1 (Fig.7,a) exopod with 12 setae; Mxp2 (Fig.7,b) outer lateral setae added to 1st and 2nd segment of endopod; Mxp3 (Fig.7,c) well developed, with 5 segmented

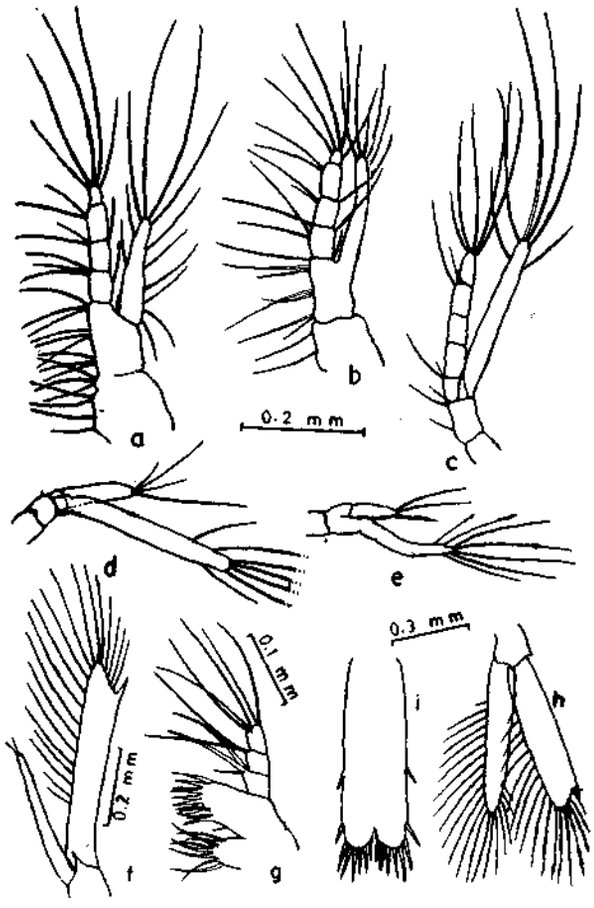

Fig. 7 *Penaeus monodon:* Mysis I: a - Mxp1; b - Mxp2; c - Mxp3; d - P1; e - P4. Mysis II: f - A2; g - Mx1; h - uropod; i - telson.

endopod, exopod tipped with 6 setae (1+4+1), some times 5 setae (0+4+1); P1 to P3 (Fig 7.d; 6,g) with endopod 2 segmented, with incipient chela, tipped with 4 long setae and one inner lateral seta, exopod with 7-8 setae (2+4+ 1 or 2+4+2); P4 and P5 (Fig,7,e) endopod tipped with 3 terminal setae, exopod with 7 or 8 setae; uropod (Fig.5,f), exopod with prominent distolateral spine followed by a short nonplumose seta shorter than distolateral spine and 16-17 long plumose setae; endopod with 16 long plumose setae. Duration of this substage was 24 to 48 hours.

MYSIS II

MCL:1.39 mm (1.34 to 1.47 mm) MTL: 4.16 mm (3.90-4.37 mm).

Rostrum usually without teeth, rarely a minute tooth may be present, no change in spination of carapace and abdomen (Fig.8,a), pleopods short, unsegmented; telson with cleft reaching to level of origin of penultimate pair of outer setae (Fig.7,i).

A1 (Fig.8, b) inner flagellum 3/4 length of outer; A2 exopod (Fig.7,f) with 19 plumose setae and a prominent distolateral spine, endopod unsegmented tipped with 2 short setae; Md (Fig.8,c) with 3 and 7 free standing teeth on right and left Md respectively, palp developed; Mx1 (Fig.7,g) without exopod, distal endite with 12 and proximal with 8 setae; Mx2 with 16 setae on exopod (Fig.8,d); Mxp1 (Fig.8,e) with

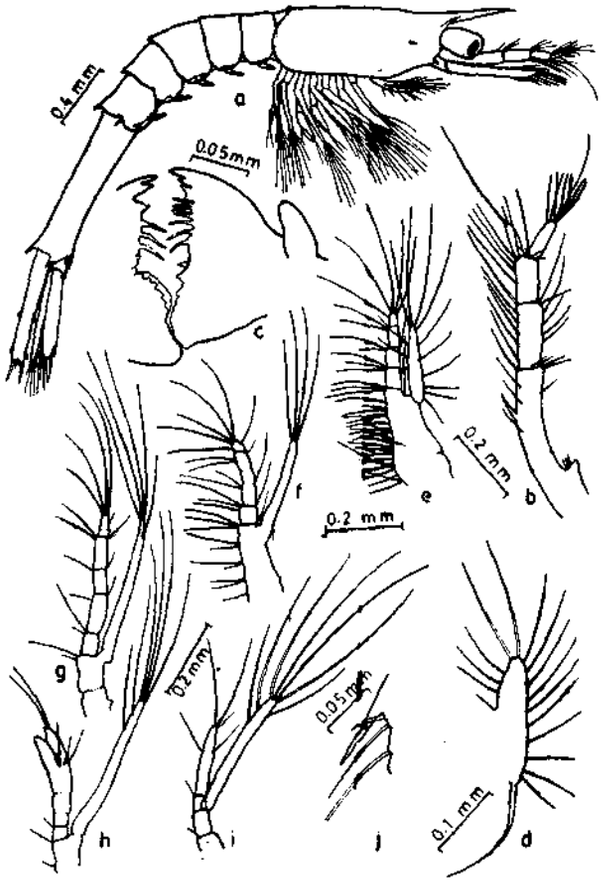

Fig. 8 *Penaeus monodon:* Mysis II: a - lateral view; b - A1; c - Md; d - Mx2 exopod; e - Mxp1; f - Mxp2; g - Mxp3; h - P1; i - P4; j - distolateral portion of exopod of uropod.

12 setae on exopod, rarely with 13 setae; Mxp2. (Fig.8,f) endopod with penultimate segment indistinctly divided into 2, distal segment with 6 setae, exopod with 4 terminal setae; Mxp3

(Fig.8,g) exopod with 0+4+1 or 1+4+1 setae; P1 to P3 (Fig.8,h) endopod 2 segmented, distal segment indistinctly divided into 3, chela developed with 2 terminal setae and 3 short setae at junction of dactylus with propodus, 1 short seta on inner margin of 1st segment, exopod with 1+4+2 or 2+4+2 long plumose setae; p4 and p5 (Fig.8,i,) endopod 2 segmented, distal segment indistinctly divided into 2, tipped with 3 setae 1st segment with 1 short outer seta, 2nd with 1 outer seta and 1 inner; uropod (Fig.7,h), endopod with 20 plumose setae, exopod with 18 plumose setae and 1 nonplumose seta shorter than prominent distolateral spine (Fig.8,j) Duration of this substage was 24-48 hours.

MYSIS III

MCL: 1.40mm (1.32-1.51 mm); MTL: 4.24mm (4.00-4.40mm).

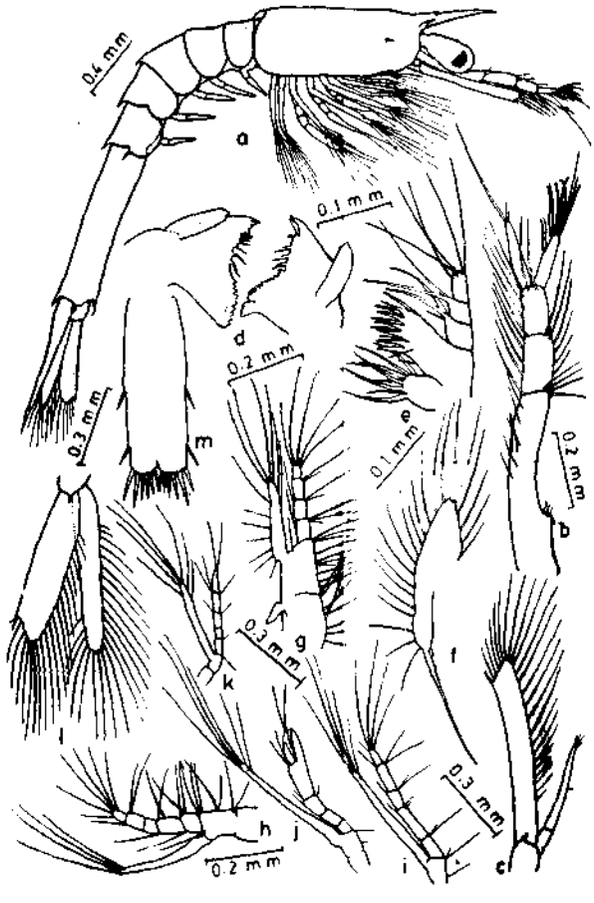

Fig. 9 *Penaeus monodon:* Mysis III: a - lateral view; b - A1; C - A2; d - Md; e - Mx1; f - exopod of Mx2; g - Mxp1; h - Mxp2; i - Mxp3; k - P4; l - uropod; m - telson.

Rostrum with 1 tooth in some specimens, no change in spination of carapce and abdomen (Fig.9,a ; pleopods long, 2 segmented without setae; cleft in telson reaching level of origin of 3rd pair of outer lateral setae on telson (fig.9,m).

A1 (Fig.,9b) with flagella unsegmented, more or less equal in length, outer with 7 aesthaetes and 2 setae, inner with 3 apical setae; A2 (Fig.9,c) with 22-23 plumose setae and a prominent distolateral spine, endopod 2 segmented; Md (Fig.9,d) with palp longer, right and left Md with 3 and 7 free standing teeth respectively; Mx1 (Fig.9,e) with 13 setae on distal endite; Mx2 with 22 setae on exopod (Fig.9,f); Mxp1 (Fig.9,g) with gill rudiment on protopod, exopod with 12, rarely 13 setae; Mxp2 (Fig.9,h) no appreciable change; Mxp3 (Fig 9,i), endopod longer than exopod which has 1+4+1 or 0+4+1 setae; P1 to P3 (Fig. 9,j) with 5 segmented endopod, well formed chelae retain the long setae; P4 and P5 (Fig. 9,k) with 5 segmented endopod, distal segment with 2 apical setae, 4th segment with 1 inner and 2 outer setae, 3rd with 1 outer and 1 inner setae, 2nd with no seta and 1st with one inner seta; uropod (Fig.9,l with 22 plumose setae on endopod, exopod with 20 plumose setae and 1 non-plumose seta shorter than distolateral spine. Duration of this substage was 24 to 48 hours.

INTERMEDIATE STAGE

MCL: 1.50mm (1.48-1.53 mm); MTL: 4.54 mm (4.49-4.59 mm).

Rostrum with 1 distinct tooth; no change in spination of carapce and abdomen (Fig. 10,a); pleopod (Fig. 10,k) with 10 plumose setae; exopods of Mxp2, Mxp3 and P1 to P5 with plumose setae; shallow cleft of telson still present (Fig.10,1).

A1 (Fig.10,b) with 3 segmented inner flagellum which is longer than 2 segmented outer flagellum; A2 (Fig.10,c) endopod 6 segmented tipped with 5 setae, exopod with 23 plumose setae and prominent distolateral spine; Md (Fig. 10, d) free standing teeth absent, palp unsegmented, with 4 setae; Mx1 (Fig. 10,e) no appreciable change; Mx2 (Fig.10,f) with 19 to 20 plumose setae on exopod; Mxp1 (10,g) exopod and endopod reduced in size, protopod segments

enlarged, gill rudiment developed; Mxp2 (Fig.10,h) endopod sigmoid, setae reduced in length; Mxp3 endopod longer than exopod, exopod setae still present; P1 to P3 (Fig.10,i) chela fully developed without long terminal setae; exopods still with setae,; P4 to P5 (Fig.

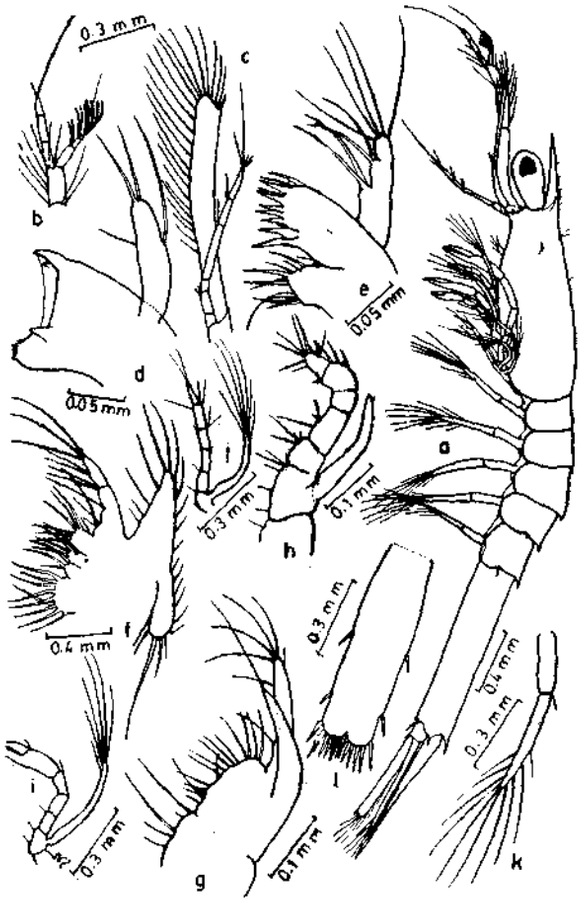

Fig. 10 *Penaeus. monodon* - Intermediate stage: a - lateral view; b - tip of A1; c - A2; d - Md; e - Mx1; f - Mx2; g - Mxp1; h - Mxp2; i - P1; j - p4; k - pleopod; l - telson.

10,j) endopods without long terminal setae, exopods retain the setae; uropod with 23 plumose setae on endopod, exopod with 22 plumose setae and 1 nonplumose seta shorter than prominent distolateral spine Duration of this substage was 24 to 30 hours.

POSTLARVA 1

MCL: 1.46 mm (1.40-1.54 mm), MTL: 4.56 mm (4.45-4.70 mm).

Rostrum with 1 distinct tooth, supraorbital spine reduced in size, no change in spination of carapace and abdomen (Fig.11,a) pleopods setose (Fig.11,1) exopods on Mxp2, Mxp3, p1 to p5 shrunken. without setae; shallow cleft in telson still present (Fig.11.b).

A1 (Fig.11,b) 3 segmented inner flagellum twice as long as 2 segmented outer flagellum; A2 (Fig.11,c) endopod 6 segmented, exopod with 25 plumose seta and prominent distolateral spine; Md(Fig.11,d) cutting edge developed, palp 2 segmented, short distal segment with 2 and longer proximal segment with 4 setae; Mx1 (Fig.11,e) setae on distal endite short and stout, endopod reduced in size, without setae; Mx2 (Fig.11,f) exopod

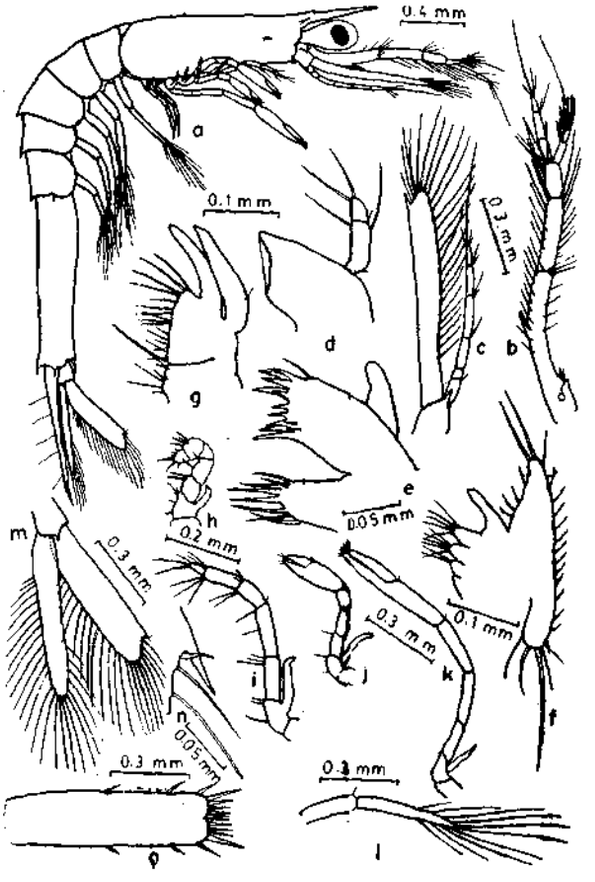

Fig. 11 *Penaeus monodon:* Postlarva I: a - lateral view; b - A1; c - A2; d - Md; e - Mx1; f - Mx2; g - Mxp1; h - Mxp2; i - Mxp3; j - P1; K - P3; l - pleopod; m - uropod; n - uropod, distolateral angle; o - telson.

with 24 setae, endopod unsegmented reduced in size; Mxp1 (Fig.,11g) protopod enlarged, exopod and endopod unsegmented. reduced in size, endopod without setae, exopod with

single outer seta; Mxp2 (Fig.11,h) recurved endopod with stout setae on distal segment, exopod shrunken without setae; Mxp3 (Fig. 11,i) shrunken exopod without setae; p1 to p3 (Fig.11,j,k) chela functional, without long terminal setae, exopod vestigial; p4 and p5 exopod vestigial; uropod (Fig.11,m), endopod with 25 plumose setae, exopod with 22 plumose setae and 1 nonplumose seta shorter than distolateral spine (Fig 11.n).

DISCUSSION

The present larval description of *P. monodon*, differs from that given by Villaluz[1] in some respects. The differences are tabulated below:

	P. monodon (Present)	*P. monodon* (Villaluz[1])
Nauplius I		
A 1	distal inner lateral seta long	distal inner lateral seta short
A 2	endopod with 4 setae, 2 inner lateral, 2 long terminal, a setal rudiment present terminally	endopod with 3 setae, 1 inner lateral, and 2 long terminal
Nauplius II		
A 1	1 long and 2 short terminal setae, 1 short outer lateral seta and 2 longer inner lateral setae	1 short and 2 long terminal setae, long outer lateral and 2 short inner lateral setae
A 2	endopod with 2 long setae and 1 setal rudiment at tip and 2 short inner setae	endopod with 2 long and 1 short seta at tip and 1 short inner lateral seta
Nauplius III		
A 1	7 setae, 2 long and 1 short at tip, 2 long and 1 minute on inner margin and 1 very thin outer lateral	5 setae, 3 long at tip and 2 long at sides
A 2	endopod with 5 setae 2 long and 1 short at tip and 2 short inner lateral	enopod with 6 setae, 3 long at tip and 3 short inner lateral
Nauplius IV		
A 1	6 setae, 2 long and 1 short at tip and 2 long and 1 short inner lateral	5 setae, 3 long at tip and 2 short at sides.
A 2	exopod with 9 setae, 2 long, 1 short and 1 rudimentary at tip, 4 long and 1 rudimentary on inner lateral margin; segments not distinct; endopod with 6 setae, 3 long and 1 rudimentary at tip, 2 short at side	exopod with 7 setae, 2 long and 2 short at tip and 3 long on inner margin, segments distinct, endopod with 5 setae, 3 long at tip and 2 short at side

Nauplius V		
A 1	7 setae, 2 long and 1 short at tip, 2 long and 1 rudimentary on inner lateral side and 1 rudimentary on outer lateral	6-7 setae, 2 long and 1 short at tip and 3-4 short at side; 2-3 tiny spines at sides
A 2	exopod segments not clear	exopod with 8 segments
Nauplius VI		
A 1	9 setae, 2 long and 1 short at tip and 2 short and 1 rudimentary on outer lateral side, 2 long and 1 rudimentary on inner lateral side, segmentation not clear	6-7 setae; 2 long and 2 short at tip and 2-3 short at sides, 2-3 tiny spines at sides, 9-11 short basal segments
A 2	exopod with 12 setae, 2 long, 1 short and 1 rudimentary at tip, 5 long, 1 short and 1 rudimentary on inner margin, and 1 rudimentary on outer margin, segmentation faint, endopod with 6-7 setae, 3 long and 1 short at tip and 2-3 short on inner margin	exopod with 10 setae. 3 long and 1 short at tip and 4 long and 2 short at sides; 9 segments, endopod with 6-7 setae, 4 long at tip and 2-3 short at side
Protozoea I		
Mx1	6 setae on proximal endite and 4 setae on distal endite	7 setae on proximal endite and 5 setae on distal endite
Mxp1	endopod with 3, 1, 2 and 5 setae	endopod with 2-3 setae on each of first 3 segments and 5 distal segments
Protozoea II		
Mx1	6 setae on proximal endite and 7 on distal endite	7 setae on proximal endite and 5 setae on distal endite
Protozoea III		
Mxp1	9 setae on exopod	7 setae on exopod
Mxp2	7 setae on exopod	6 setae on exopod
Mysis I		
Mxp1	exopod with 12 setae	exopod same as in protozoea stage
Uropod	17-18 setae on exopod and 16 setae on endopod	16-17 setae on exopod and 15-16 setae on endopod

Mysis II		
A 2	exopod with 19 setae	exopod with 17-18 setae
Uropod	exopod with 19 setae, endopod with 20 setae	exopod with 19-21 setae, endopod with 17-19 setae
Mysis III		
A 1	outer and inner flagellum not segmented	outer flagellum with 2 faint segmentations, inner with 3 faint segmentations
A 2	endopod 2 segmented	endopod with 4 faint segments
Mx2	exopod with 22 setae	exopod with 19-20 aetae
Postlarva I		
uropod	endopod with 25 and exopod with 23 setae	endopod with 22-23 and exopod with 21-22 setae

The intermediate stage described here is not mentioned by Villaluz *et. al.* [1]. Even during the present study the intermediate stage was rare and is probably a deviation 'rom the normal course of larval development.

III

Larval development — *PENAEUS INDICUS* H. MILNE EDWARDS

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N. N. Pillai
K. V. George

The larvae ot *Penaeus indicus* reared from eggs spawned in the laboratory are discribed and illustrated and compared with earlier descriptions of the species. At the rearing temperature of 24.4°C to 26.8°C the nauplii hatched out of the eggs 16-17 hours after spawing; the nauplius stage lasted 40-50 hours and the protozoea and mysis stages 4-6½ and 4-7 days respectivley. The larvae passed through 6 nauplius substages, 3 protozoea substages and 3 mysis substages before reaching postlarva I stage.

Based on material from plankton samples, Menon (1937, *Bull. Madras. Govt. Mus. Natural Hist. Sec.* 3 (5): 1-56[1]), Mohamed *et.al.* (1968, *FAO. Fish. Rep.*, 57(2): 487-504[2]), Rao (1973, *J. mar. biol. Ass. India*, 15(1): 95-124[3]); and Subrahmanyam (1965,. *J. mar. biol. Ass. India*. 7 (1) :83-88[4]) described some stages of penaeid larvae, attributing them to *Penaeus indicus* on circumstantial evidence. The present studies based on spawning and rearing of *P. indicus*

at the Narakkal Prawn Culture Laboratory of the Central Marine Fisheries Research Institute during January-March 1976 showed that the larval features of *P. indicus* are different from these early descriptions. A detailed description of the eggs and larvae of this commercially important species is presented here. The temperature and salinity of the water in the rearing basins was 24.4° C-26.8° C and 33.8‰-34.1‰ respectively.

The authors are grateful to Dr. E.G.Silas Director, Central Marine Fisheries Research Institute, for the encouragement and facilities provided and for his valuable suggestions.

DESCRIPTION OF DEVELOPMENTAL STAGES

EGGS

Eggs opaque, with a narrow perivitelline space, chorion has a purplish sheen, diameter of eggs varied from 0.25 to 0.27 mm and that of yolk mass 0.22 to 0.24 mm.

The eggs when first observed at 23.45 hours were covered with a gradiating jelly like substance which partly dissolved and became granular while being observed under the microscope, and disappeared after 3 minutes. The egg was then spherical but without perivitelline space and appeared to be still invested with jelly like substance which was transparent. A polar body was seen adhering to the surface of the egg. Within one minute the perivitelline space was formed by the elevation of the fertilization membrane (Fig. 1,a) and the egg assumed the definitive form (Fig.1,b). Immediately after a second polar body was seen coming out of the yolk mass and traversing the perivitelline space just below the first polar body and soon reached the surface of the egg. The first cleavage began at 00.15 hours, about 30 minutes after the extrusion of the eggs (Fig.1,c). The second cleavage (Fig.1,d) took place at 00.30 hours. The cleavage continued (Fig.1,e,) and at 01.30 hours the blastula stage was observed (Fig. 1,f). An embryonic membrane was clearly visible during the blastula stage. Gastrulation (Fig.1,g) started at 02.15 hours and continued up to 02.55 hours. At 04.50 hours the embryonal mass became constricted laterally and the appendages started differentiating (Fig.1, h, i, j,). By 07.45 hours all the 3 naupliar appendages could be seen as lateral thickenings (Fig.1,k) which became tipped with short spine-like setae by 09.45 hours (Fig. 1,l). At 13.00 hours the 3 appendages were fully formed with long setae. The embryo occupied the entire space inside the egg and

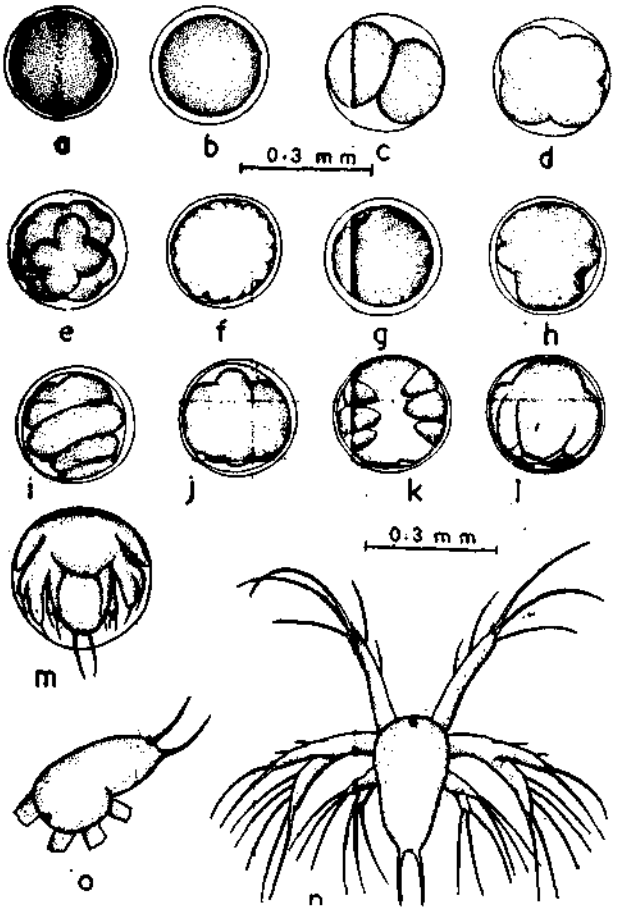

Fig. 1 *Penaeus indicus*: a to l - egg in various stages of development; m - egg with nauplius inside; n - Nauplius I; o - lateral view of Nauplius I.

the movements were restricted to sudden jerks of appendages. The furcal setae first pierced the egg membrane (Fig.1,m) and the nauplius wriggled out of the egg 16 to 17 hours after the eggs were spawned.

NAUPLIUS I

MTL: 0.30 mm (0.28 - 0.31 mm);MW: 0.17 mm (0.15-0.17 mm); MFS: 0.13 mm (0.11-0.14 mm).

An ocellus present at anterior median

region of body, dorsal surface of body bears posteriorly a small median denticle (Fig.1,o) a pair of dorsally curved caudal setae present at posterior end of body, 3 pairs of appendages present (Fig.1,n); A1 uniramous, with 2 long setae of almost same length and a small rudimentary spine-like seta at its apex, 2 short setae on inner distal margin and one long seta on outer distal margin; A2 biramous, endopod shorter than exopod, bearing 2 long setae and one rudimentary seta at apex, and 2 short setae along inner margin, exopod carries 5 long setae along inner margin and tip; Md biramous, shorter than other appendages, bearing 3 long setae on endopod and exopod; setae of appendages nonplumose.Duration of this substage was 4 to 4 hours.

NAUPLIUS II

MTL: 0.31 mm (0.29-0.32 mm); MW: 0.17mm (0.15-0.18 mm); MFS: 0.14 mm (0.13-0.15mm).

Setae on appendages plumose; no change in number of setae on A1, but outer terminal and outer lateral setae distinctly smaller than in Nauplius I, inner distal rudimentary seta of nauplius I transformed into a short seta; exopod of A2 with an additional rudimentary seta on outer distal margin, the 4th seta counting from the proximal end bifurcates (Fig.2,a), this bifurcate condition is retained in later naupliar substages; Md comparatively longer; furcal setae show a faint demarcation at proximal 1/3; duration of this substage is 3 to 4 hours.

NAUPLIUS III

MTL: 0.31 mm(0.29-0,32mm); MW: 0.16 mm (0.14-0.17 mm); MFS: 0.14mm (0.13-0.15 mm).

No appreciable increase in body measurements; furcal lobes each with 3 setae (Fig. 2,b) of which innermost very small and slightly ventrally placed and hence not clearly visible in dorsal view; no increase in number of setae on appendages; among A1 setae inner terminal seta longer and outer terminal seta shorter than in nauplius II; rudimentary setae at tip of A2 exopod and endopod in nauplius II has become longer and plumose. Duration of this substage is 6 to 8 hours.

NAUPLIUS IV

MTL: 0.36 mm (0.34-0.38 mm);MW: 0.17 mm (0.15-0.18 mm);MFS: 0.20 mm (0.19-0.21 mm).

The furcal lobes become more distinct and bear 4 setae (Fig.2,c) each, outermost

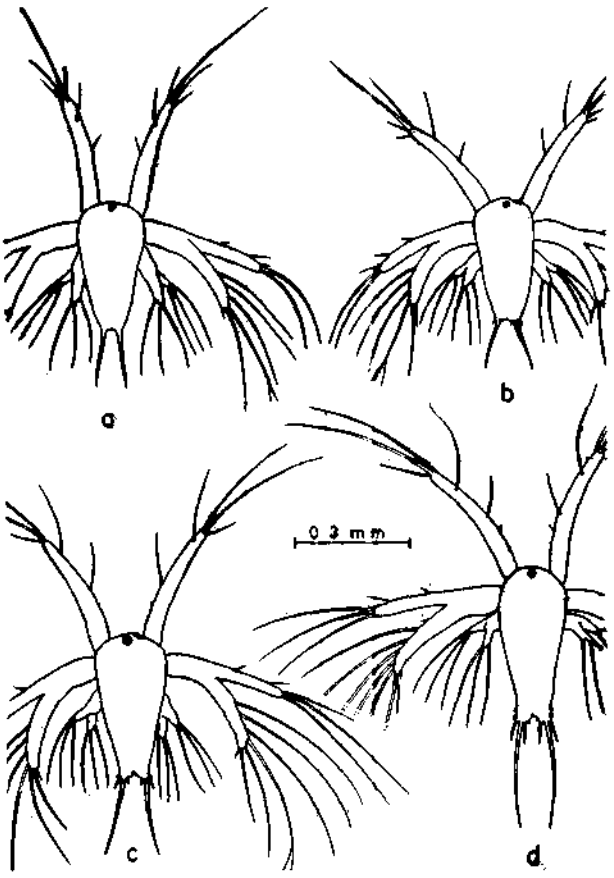

Fig. 2 *Penaeus indicus:* a - Nauplius II; b - Nauplius III; c - Nauplius iv; d - Nauplius v.

seta smallest and being dorsally placed not clearly visible in ventral view; rudiments of developing Mx1, Mx2, Mxp1, Mxp3 seen inside cuticle; A1 outer lateral seta lost and one very small seta added on inner lateral aspect proximally; proximal portion with indistinct segmentation; exopod of A2 with 6 long plumose setae and one rudimentary spine-like seta distally, indistinct segmentation seen in exopod, inner terminal seta on A2 endopod longer. Duration of this substage is 3 to 4 hours.

NAUPLIUS V

MTL: 0.38 mm (0.35-0.41 mm); MW: 0.17 mm (0.15-0.20 mm); MFS: 0.23 mm(0.20-0.28 mm).

Furcal lobes well developed, each carrying 6 setae (Fig. 2,d), minute outermost one being dorsally placed; rudimentary oral appendages become biramous; endopod of A2 with 2 short setae on inner lateral margin and 3 long plumose setae and 1 rudimentary seta terminally, exopod with 9 setae along inner and distal margin, of which distal outer and inner proximal rudimentary and spine like; a prominent rounded swelling appears at base of Md; no change in A1 setation. Duration of this substage was 10 to 12 hours.

NAUPLIUS VI

MTL: 0.48 mm (0.43-0.54 mm); MW: 0.20 mm (0.18-0.21mm); MFS: 0.31 mm (0.29-0.34 mm).

Body more elongated, frontal organ and carapace clearly demarcated (Fig.3,a,b), appendages not clearly segmented, but surface with annular indentations, furcal lobes with 7 setae each (Fig. 3,b); one minute and 2 short setae added to A1 on distolateral aspect, A1 proximally with 5 indistinct segments; endopod of A2 with 3 long setae and 1 short one terminally and with a rudimentary seta added to root of distal seta on inner lateral margin, exopod with 10 setae along inner and distal margin, of which newly added distal outer one rudimentary. Duration of this substage was 15 to 24 hours.

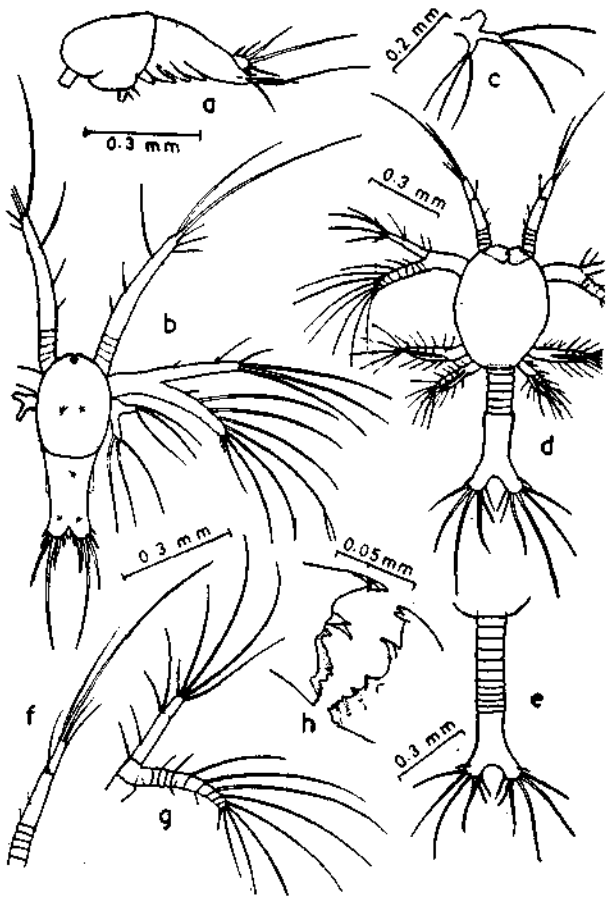

Fig. 3 *Penaeus indicus;* a - Nauplius VI lateral view; b - dorsal view of Naudlius VI; c - Md of Nauplius VI. Protozoea I: d - dorsal view; e - abdomen of advanced stage; f - A 1; g - A2; h - Md.

PROTOZOEA I

MTL: 0.88 mm (0.88-0.91 mm); MCL: 0.42 mm

Carapace anteriorly rounded, with median notch. frontal organs present as rounded protuberances, ocellus of nauplius persists, developing compound eyes covered with carapace, body divisible into 3 parts, carapace covered anterior region, 6 segmented thorax in middle and posterior unsegmented abdomen; newly hatched protozoea with a swelling in anterior part of the abdomen (Fig.3,d) which is replaced in advanced protozoea I by 5 somites resulting in lengthening of abdomen (Fig.3,e); last abdominal somite and telson not separated by a movable joint, each lobe of caudal furca with 7 setae, outermost seta originates from dorsolateral aspect of furca and is dorsally disposed.

A1 (Fig.3,f) 3 segmented, basal segment with 5 subsegments, middle segment with 3 setae and distal segment with 2 setae of which one is long, about twice length of A1 peduncle and 2 aesthaetes, a spike-like setal rudiment present on distal inner margin of terminal segment; A2 (Fig.3,g) biramous, endopod 2 segmented and exopod 10 segmented, 1st segment of endopod with 4 plumose setae of which 2 are placed together near inner distal margin of 1st joint, distal segment with 5 plumose setae of which inner one is smallest, exopod with 11 plumose setae along inner and distal margin and 2 small setae on outer margin; Md (Fig.3,h) flattened, without exopod and endopod, incisor process with 2 or 3 teeth and molar with transverse rows of smaller grinding teeth 1 free standing tooth present between molar and incisor process; Mx1 (Fig.4,a) with unsegmented protopod having 2 lobes, proximal with 7 and distal with

4 setae, some setae stout and distally spinose, exopod small, knob like with 4 long feathery setae, endopod 3 segmented, distal segment carries 5 long plumose setae, basal and middle segments carry 3 and 2plumose setae respectively; Mx2 (Fig.4,b) with protopod having 5 lobes on inner margin, 1st lobe with 7 or 8 setae, 2nd and 3rd with 4 setae and 4th and 5th with 3 setae respectively, exopod knob-like, with 5

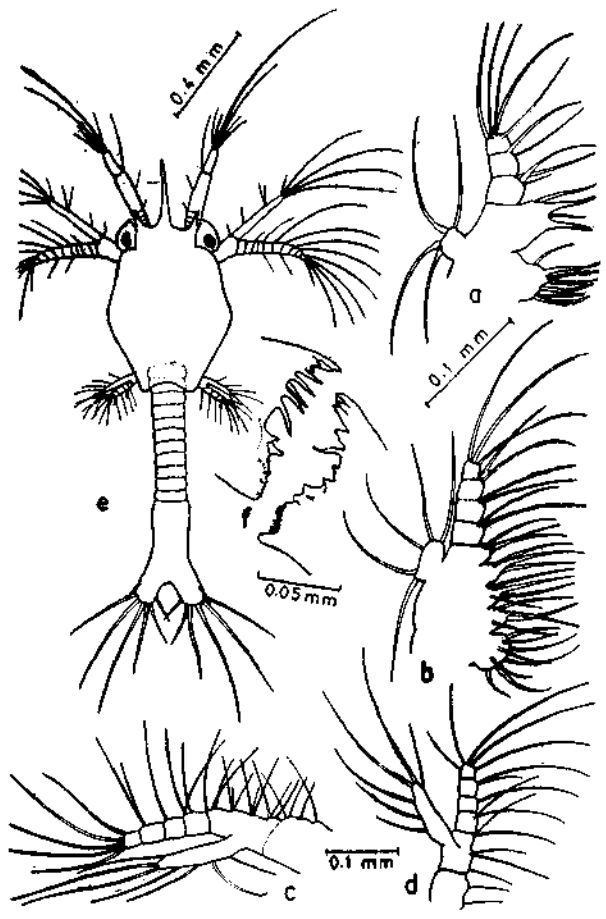

Fig. 4 *Penaeus indicus:* Protozoea I: a - Mx1; b - Mx2; c - Mxp1; d - Mxp2. Protozoea II: e - dorsal view; f - Md.

long feathery setae, endopod 4 segmented, terminal segment with 3 long setae distally, the other 3 segments each with 2 long setae on inner margin; Mxp1 (Fig.4,c) biramous, longer than Mx2, protopod 2 jointed, coxa with 4 to 5 and basis with 12 setae along inner margin, exopod unsegmented, carrying 7 plumose setae, 4 along outer margin, 2 terminal and one subterminal on inner margin, endopod 4 segmented, 1st, 2nd, 3rd and 4th segments carry 3, 1, 2 and 5 long plumose setae respectively; Mxp2 (Fig.4,d) shorter than Mxp1, protopod 2 segmented, coxa with 2 and basis with 5 setae along inner margin, exopod unsegmented, with 6 plumose setae; 3 along outer margin, 2 terminal and one subterminal on inner margin, endopod 4 segmented, carrying 2, 1, 2, and 5 plumose setae on segments 1, 2, 3 and 4 respectively. Duration of this substage was 24 to 48 hours.

PROTOZOEA II

MTL: 1.52 mm (1.40-1.55 mm); MCL: 0.74 mm (0.71-0.76 mm).

Presence of a well developed curved rostrum, bifurcated supraorbital spines (Fig. 4,e), stalked compound eyes and absence of frontal organs distinguish this substage from the previous one.

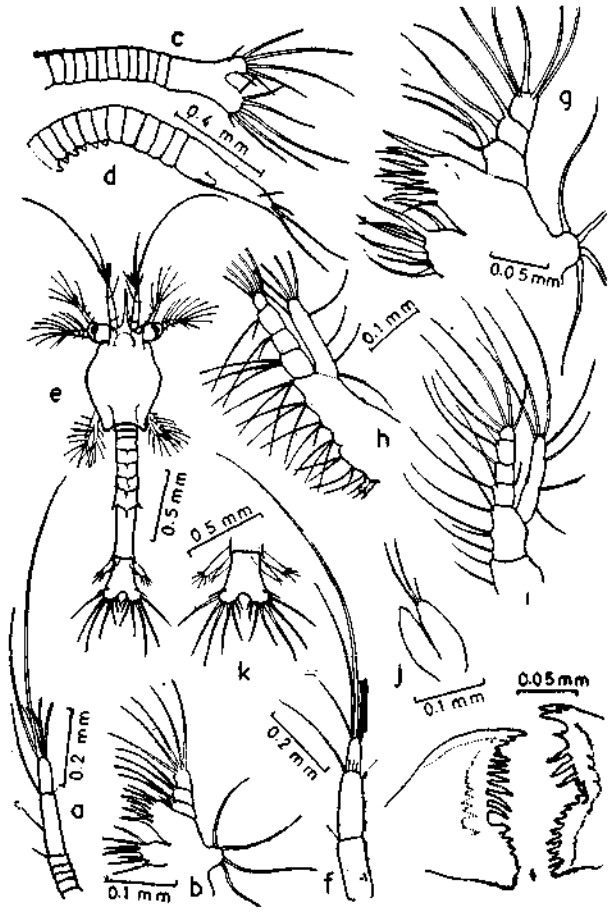

Fig. 5 *Penaeus indicus:* Protozoea II: a - A1; b - Mx1; c - abdomen of early stage; d - abdomen of late stage. Protozoea III: e - dorsal view; f - A1; g - Mx1; h - Mxp1; i - Mxp2; j - Mxp3; k - uropod and telson. Mysis I: l - Md.

A1 (Fig.5,a) with distal segment bearing 4 aesthaetes and 2 long setae; Md (Fig.4,f) asymmetrical, right and left Md with 1 and 5 free standing teeth between incisor and molar processes; Mx1 (Fig.5,b) with 8 setae on distal lobe of protopod; Mxp1 with 2 plumose setae on 2nd segment of endopod.

As in the previous stage, the larvae show increase in length towards end of this stage. There is a definite increase in body length, MTL being 1.88 mm (1.72-1.99 mm) and MCL: 0 83 mm (0.78-0 84 mm). Advanced stage of protozoea II (Fig.5,d) can be easily distinguished from the early stage (Fig.5,c) by the presence of developing buds of five pereopods and Mxp3 and by the increase in length of abdominal segments. Moreover, the developing uropods can be clearly seen inside the lobes of caudal furca. Duration of this substage was 48 to 72 hours.

PROTOZOEA III

MTL: 2.69mm (2.41-2.73 mm); MCL: 1.01 mm (0.98-1.05 mm).

Supraorbital spines not bifurcate, telson demarcated from 6th abdominal segment by an articulating joint, abdominal segment 1 to 5 with dorsomedian spine on posterior border, 5th and 6th abdominal segments have each a pair of posterolateral spines (Fig.5,e), 6th segment devoid of posteromedian dorsal spine, but with a pair of ventrolateral spines, caudal furcae bear 8 setae each, a pair of biramous uropods present, exopod of uropod slightly longer than endopod and bears 6 terminal setae, endopod has 2 terminal setae, buds of pereopod and Mxp3 well developed and biramous, exopod bud of Mxp3 with 3 terminal setae (Fig.5,j); in advanced larvae of this substage, exopod and endopod of uropod are almost of same size and uropod rami reach much beyond middle of telson (Fig. 5,k); an increase in length of biramous buds of thoracic legs is also noticed.

A1 (Fig.5, f) 3 segmented, subsegments of basal segment fused into one, basal segment with one distal seta, 2nd segment with 2 lateral setae and 3 to 4 setules, distal segment with 3 or 4 aesthaetes and 3 setae of which one is long being more than twice length of peduncle, distal segment appears to be the forerunner of outer A1 flagellum; Md asymmetrical, between incisor and molar processes there are 6 free standing teeth in left Md and 2 free standing teeth in right Md; Mx1 (Fig. 5, g) with 10 setae on distal endite of protopod while setation on proximal endite remains unchanged; Mx2 with more setae on protopod endites, exopod and endopod remaining unchanged; Mxp1 (Fig.5,h) with 8 setae on coxa and 12 setae on basis of protopod and 9 setae on exopod; Mxp2 (Fig 5, i) with 7 setae on exopod and one additional seta on outer margin of 1st segment of endopod, protopod with 2 setae on coxa and 5 setae on basis. Duration of this substage was 24 to 36 hours.

MYSIS I

MTL: 3.36 mm (3.07-3.65 mm); MCL: 1.17 mm (1.12-1.26 mm).

Larvae assume more or less a shrimp like

Fig. 6 *Penaeus indicus:* Mysis I: a - lateral view; b - A1; c - A2; d - Mx1; e - Mx2; f - Mxp1; g - Mxp2; h - Mxp3; i - P1; j - P5; k - uropod and telson.

appearance in this stage, rostrum long and curved extending beyond eye, devoid of rostral spines, supraorbital prominent, a small spine present at anteroventral angle of carapace, hepatic spine well developed (Fig. 6,a), carapace covers thoracic region completely and thoracic appendages are well developed; posterolateral spines persist on 5th and 6th abdominal segments, dorsal spines present on posterior margin of 4th, 5th and 6th abdominal segments, in some specimens on 3rd segment also, in rare cases even the 1st and 2nd abdominal segments possess a dorsal spine; minute pleopod buds seen on 1st five abdominal segments; 6th abdominal segment develops a ventromedian curved spine at junction with telson, ventrolateral spines on posterior end retained; telson broader distally with a median notch, each lobe bearing 2 lateral and 6 terminal setae (Fig. 6, k), cleft extends to level half way between origin of outermost and penultimate pair of setae.

A1 (Fig.6, b) with 3 segmented peduncle, 1st segment longest with a ventromedian serrated spine, base of this segment swollen due to developing statocyst and carries 2 short plumose setae, numerous setae occur along appendage, distal segment carries 2 unsegmented rudiments of flagellae, inner one small and knob like carrying 1 very long and another short seta at its apex, outer flagellum carries on distal margin 3 setae and 4 aesthaetes; A2 (Fig 6, c) with endopod unsegmented carrying 3 terminal setae, one proximal seta on inner margin and 2 small setae near a very small knob-like projection on inner side distally, exopod unsegmented, leaf like, with a distolateral seta on outer margin and 11 setae on distal and inner lateral margin; Md (Fig. 5, 1) asymmetrical, with 7 free standing teeth in left Md and 3 in right Md, molar part shows a number of hard ridges bearing small teeth; Mx1 (Fig. 6, d), proximal segment of protopod with 8 setae; Mx2 (Fig.6,e) with exopod enlarged to form scaphognathite carrying 10 plumose setae, proximal one being long and thick; Mxp1 (Fig.6, f) with some setae on inner side of protopod longer and stouter, setae on coxa reduced to 5, exopod with 12 plumose setae, one seta each added to outer margin of 1st and 2nd segments of endopod: Mxp2 (Fig, 6,g) with 7 setae on basis of protopod, exopod as long as endopod carrying only 6 setae, 4 apical and 2 subapical, endopod 4 segmented, first 2 segments carry 1 seta on the outer side, terminal segment with 5 setae; Mxp3 (Fig. 6,h) well developed, protopod with 3 setae on basis, coxa without seta, endopod 5 segmented, terminal segment with 1 short and 5 long setae, 1st, 2nd and 4th segments each with 2 setae, 3rd segment naked, exopod as long as endopod carrying 4 apical and 3-4 subapical plumose setae; P considerably enlarged and their exopods serve as main swimming organs; P1, P2 and P3 almost identical, endopod segmentation indistinct, developing chelae with 5 long slender setae, exopod twice length of endopod with 4 apical and 3-4 subapical plumose setae (Fig.6,i); P4 and P5 almost identical, endopod unsegmented, half size of exopod, and bears 4 long setae apically, exopod with 4 long apical and 2 subapical setae (Fig.6,j); uropods well developed, protopod with a large posteroventral spine, exopod with a prominent posterolateral spine followed by a short nonplumose seta and about 15 plumose setae along distal and inner margin, endopod with 14 plumose setae along inner and distolateral margin. Duration of this substage was 48 to 72 hours.

MYSIS II

MTL: 3.50mm (3.39-3.58mm); MCL:1.20mm (1.15-1.26mm).

Presence of a spine on scaphocerite and appearance of unsegmented pleopod buds (Fig. 7, a) distinguish this substage from mysis I; no change in spination of carapace and abdomen; cleft on telson extends to level of origin of penultimate pair of lateral telsonic setae.

A1 with increased number of setae on peduncle, inner flagellum has increased in length and outer flagellum which is longer than inner with 6 aesthaetes and 1 or 2 setae at distal end; A2 (Fig.7,b) with a small ventral spine on outer distal end of 2nd segment of protopod, endopod nearly half length of exopod bearing a short apical seta, exopod with 19 long plumose setae along inner and distal margin and 1 spine at distal lateral angle; Md (Fig.7,c) with small unsegmented palp, 8 free standing teeth on left and 3 on right Md; Mx1 without exopod, size of endopod reduced; Mx2 with 14 to 15 plumose setae on exopod; Mxp1 with 12 setae on exopod; Mxp2 with 5 segmented endopod, with newly

added segment in middle without setae, terminal segment with 6 setae; Mxp3 (Fig.7,d) with endopod longer than exopod, 3rd segment with 2 setae, a seta added to outer distal margin of 4th segment; P1 P2 and P3 almost identical (Fig.7,e) endopod 5 segmented, distal segment with 2 and penultimate segment with 3 long setae, endopod of P4 and P5 (Fig.7, f) 4 segmented, distal segment with 2 apical

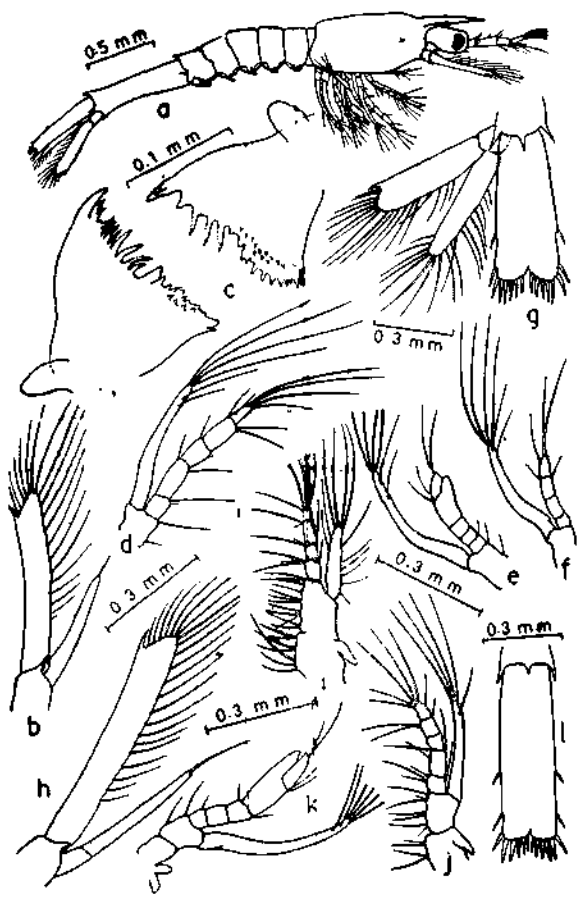

Fig. 7 *Penaeus indicus:* Mysis II: a - lateral view; b - A2; c - Md; d - Mxp3; e - P1; f - P5; g - uropod and telson. Masis III: h - A2; i - Mxp1; j - Mxp2; k - P1; l - telson.

and 1 subapical setae, penultimate segment bears 2 setae; pleopods have a slight constriction in the middle indicating the begining of segmentation; exopod and endopod of uropod with 18 setae. Duration of this substage was 24 to 48 hours.

MYSIS III

MTL: 3.90 mm (3.43-4.17 mm); MCL: 1.26 mm (1.12-1.37 mm).

Development of 2 segmented pleopod bud (Fig. 8, e) distinguishes this substage from mysis II, no change in spination of carapace and abdomen, but a very minute rudiment of rostral tooth may be seen in a few specimens; telson (Fig.7,l) long and rectangular carrying 6 distal and 2 lateral setae on each side, cleft extending to level of origin of 3rd pair of setae.

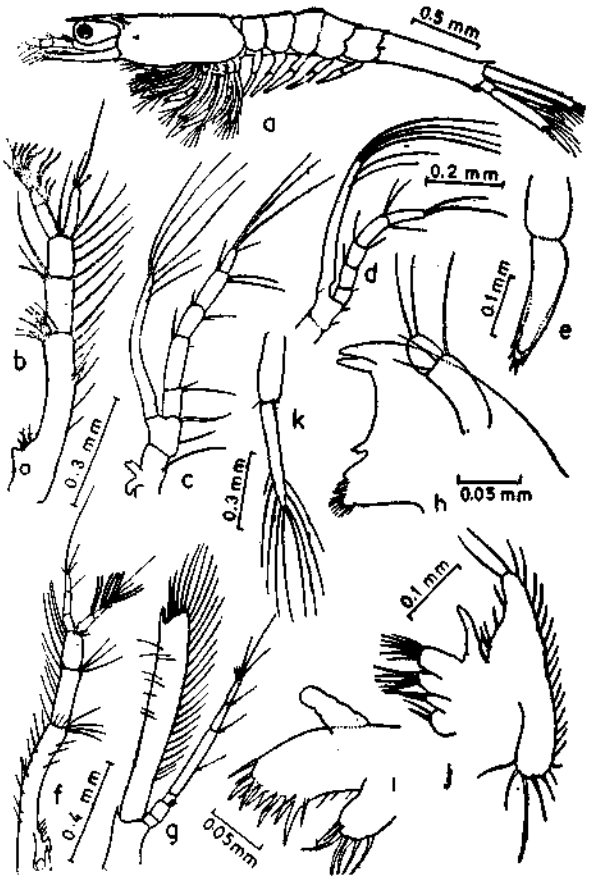

Fig. 8 *Penaeus indicus*: Mysis III: a - lateral view; b - A1; c - Mxp3; d - P5; e - pleopod bud. Postlarva I: f - A1; g - A2; h - Md; i - Mx1; j - Mx2; k; pleopod.

A1 (Fig.8,b) statocyst clearly seen, both flagella are of equal size, inner unsegmented, bearing 4 long slender setae apically, of which one is longer, outer flagellum 2 segmented with 6 to 7 aesthaetes and 2 setae on the distal segment and 2 aesthaetes on the proximal segment; A2 (Fig.7,h) with 2 segmented endopod carrying a long seta apically, exopod with 21 to 22 plumose setae and one anterolateral spine; Md still asymmetrical, palp long, but unsegmented; Mx2 with 19 setae on exopod, rudiments of gills present as protuberance on

bases of protopod of Mxp; Mxp1 (Fig.7,i) with 12 setae on exopod; Mxp2 with an outer distal seta added to 4th segment of endopod; Mxp3 (Fig.8,c) with endopod longer than exopod, distal segment with 1 short and 3 long setae; P1 (Fig.7,k) with rudiment of gill developed at base of protopod, endopod 5 segmented, chela as long as the other 3 segments put together, dactylus apically bearing 2 long setae, propodus with 2 setae at its joint with dactylus; P4 and P5 (Fig.8,d) are identical, exopod as long as endopod, distal segment of endopod with 2 slender setae apically; exopod with 4 apical and 3-4 subapical plumose setae; pleopods 2 segmented and non-setose; distally some pleopods have developing setae (Fig.8,e); uropod with 22 setae on exopod and 21 setae on endopod (Fig.7,l). Duration of this substage was 24 to 48 hours.

POSTLARVA I

MTL: 5.03 mm (4.55 - 5.26 mm); MCL: 1.53 mm (1.44 - 1.61 mm).

Rostrum with 1 or 2 dorsal spines, supraorbital, hepatic and pterygostomial spines present, the latter often very small, median dorsal spines usually present on 4th, 5th and 6th abdominal segments (Fig.9,a), lateral spines present on 5th and 6th abdominal segments, anal spine still present on 6th abdominal segment, exopods of P small and without setae, pleopods well developed and setose, telson (Fig. 9, j) rectangular in shape carrying 3 pairs of lateral and 5 pairs of terminal setae' median notch practically absent.

Al (Fig.8,f) with statocyst at base of 1st segment, well developed ventromedian spine still present on basal segment; inner branch of distal segment 3 segmented, longer than outer and carries 4 setae apically, of which 1 is as long as the branch, outer branch 2 segmented carrying 8 aesthaetes and 3 setae; A2 (Fig.8,g) with endopod 6 segmented, distal segment apically bearing 3 long and 3 short setae; exopod with 27 setae and one anterolateral spine; Md (Fig. 8,h) has become almost symmetrical, free standing teeth lost, palp well developed and 2 segmented, carrying setae; Mx1 (Fig.8.i) with endopod much reduced, unsegmented and without setae; distal lobe of protopod larger than proximal, distal and proximal lobes with 13 to 18 and 7 to 8 setae respectively; Mx2 (Fig.8,j) with much reduced protopod having 4 endites, proximal 2 endites with 2 setae, distal 2 endites carry 5 to 6 bristle like setae, endopod reduced,

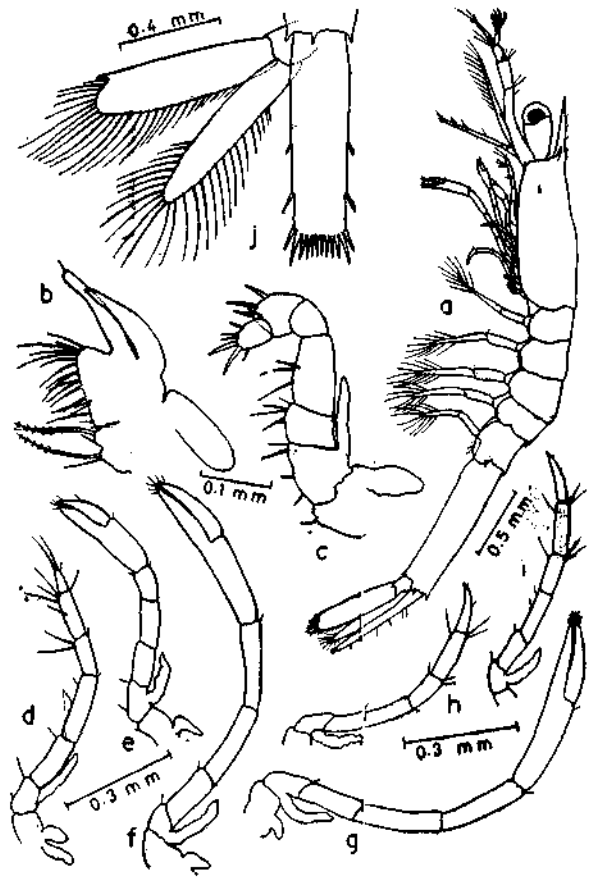

Fig. 9 *Penaeus indicus:* Postlarva 1: a - lateral view; b - Mxp1; c - Mxp2; d - Mxp3; e - P1; f - P2; g - P3; h - P4; i - P5; j - uropod and telson.

unsegmented, without setae, scaphognathite very conspicuous bearing 29 to 30 plumose setae; Mxp1 (Fig.9,b) with endopod and exopod reduced in size without segments and setae, protopod has become wide with numerous setae, epipod well developed; Mxp2 (Fig.9,c) with exopod vestigial, endopod recurved, distal segment with 6 spine-like setae, penultimate segment naked, protopod carries a gill; Mxp3 (Fig.9,d) with gill on protopod, exopod rudimentary without setae, 4th segment of endopod with 5 setae; P1 (Fig.9,e) with rudimentary gill on protopod, exopod much

reduced, without setae, chelae fully developed; P2 and P3 (Fig.9,f.g) progressively longer than P1; P4 and P5 (Fig.9,h,i) almost similar, exopod reduced, endopod 5 segmented, 3rd and 4th segments carry 3 setae each; 26 to 27 setae on margin of exopod and endopod of uropod (Fig.9,j). Duration of this substage was 24 to 30 hours.

DISCUSSION

Earlier authors working with material collected from the plankton have described various larval stages of *Penaeus indicus*. Menon[1] has described protozoea I, II and III and mysis I from plankton of Madras coast. Subrahmanyam[4] described eggs and 3 naupliar stages also from Madras. Rao[3] described mysis I, II and III from Cochin waters It is now clear that, except for some of the stages described by Menon[1], the larvae described by these authors do not belong to the genus *Penaeus*. The large size (0.45-0.47 mm) and wide perivitelline space of the eggs described by Subrahmanyam[4] show that they cannot belong to *P. indicus* which has a smaller egg (0.27 mm) with a very narrow perivitelline space. There is very little difference between the figures of the eggs and nauplii of *M. dobsoni* given by Menon (1951, *Proc. Indo Pacif. Fish Counc. 3rd meeting.* Sec II: 80-93.[5]) and the figures given by Subrahmanyam[4]. The protozoea II and mysis I described by Menon[1] possess the characters typical of the genus *Penaeus* and hence could belong to *P. indicus*, but the protozoea III described by him clearly does not belong to the genus *Penaeus*, as it has only 7 pairs of telsonic setae and has a pair of well formed Mxp3 with setae on both the exopods and endopods; the presence of a small tooth at the base of the rostrum on either side, in addition to the supraorbital spine is also a character that is not found in the genus *Penaeus*. The first protozoea described by Menon[1] closely resembles the present description but differs from it in the possession of 6 terminal setae on A1 and in the presence of 2+2 setae on the lateral aspect of A2 endopod. The mysis substages described by Rao[3] as those of *P. indicus* are different from the present description and do not belong to *P. indicus* for the following reasons: (1) 5th and 6th abdominal segments do not possess posterolateral spines. (2) the supraorbital spine is minute, (3) small antennal spine is present, (4) the hepatic spine is absent in mysis I, (5) a rostral spine is present even in mysis I and II and 2 rostral spines are seen in mysis III, (6) the shape of the telson is clearly different and the median cleft is absent in mysis II and III, (7) the A2 scale of mysis I has an anterolateral spine and (8) the A2 scale of mysis II and III is very broad and the A2 endopod of mysis III is actually longer than the A2 scale. Many of these characters are common to the mysis stage of *Parapenaeopsis stylifera*. The postlarva I of *P. indicus* described by Mohamed *et. al*[2]. differs from the present description in the following respects: (1) the absence of posterolateral spines on 5th and 6th abdominal segments, (2) the absence of pterygostomial spines and (3) the absence of shrunken exopods of Mxp2 and Mxp3 and P1 to P5. It appears to be a later stage postlarva of *P. indicus*.

IV

Larval development — III *PENAEUS SEMISULCATUS* DE HAAN

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The larvae of *Penaeus semisulcatus* reared from eggs spawned in the laboratory are described and illustrated for the first time. At a rearing temperature of 31.0°c the nauplii hatched out 12 to 13 hours after spawning; the duration of the nauplius, protozoea and mysis stages was 42 hours, 154 hours and 96 hours respectively. The larvae passed through 6 nauplius substages, 3 protozoea substages and 3 mysis substages before transforming into postlarva I.

The green tiger prawn *Penaeus semisulcatus* which is commercially important on the Tamil-nadu coast, spawned during September 1977 in the Kovalam Field Laboratory of the Central Marine Fisheries Research Institute, Madras Research Centre and the larvae were successfully reared to the postlarval stage. Though some information on the spawning and larval forms of *P. semisulcatus* from Taiwan (Liao and Huang, 1973, *In* Coastal Aquaculture in the Indo-Pacific Region, Fishing News (Books) Ltd., London, 328-354)and from Madagascar(Courties, 1976, *Cah. O, R. S. T. O. M. Ser. Oceanoger,* 14 (1); 49-70.) are available, detailed morphology of various larval stages of the species are not known. Hence, a complete description of different larval stages of *P. semisulcatus* along with necessary illustrations are given for the first time in this paper. Temperature of the water in the rearing basins was 31.0°C and the salinity 35.2‰.

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DESCRIPTION OF LARVAL STAGES

EGG

Spherical, diameter ranging from 0.27 to 0.29mm (mean 0.28 mm) (Fig.1,a). The nauplius hatches out of the egg 12-13 hours after spawning.

NAUPLIUS I

MTL: 0.30 mm (0.28-0.31 mm); MW: 0.16 mm (0.15-0.17 mm) MFS: 0.12 mm (0.11-0.13).

Typical penaeid nauplius with pyriform unsegmented body having ventrally projecting labrum, ocellus present as dark spot in anterior median region, persisting in all nauplius substages (Fig. 1,b), body smooth except for a small denticle on posterior margin dorsally, a pair of caudal setae present.

A1 uniramous, having terminally 1 small spike- like seta and 2 long setae, 1 long seta on distal outer margin as long as terminal setae, and 2 small setae on inner margin in distal half, in some specimens, an additional small seta seen at middle of proximal half; A 2 biramous, endopod with 1 rudimentary and 2 long setae

distally and 2 short setae on inner margin, exopod with 5 long setae along inner and distal margin; Md biramous, exopod and endopod

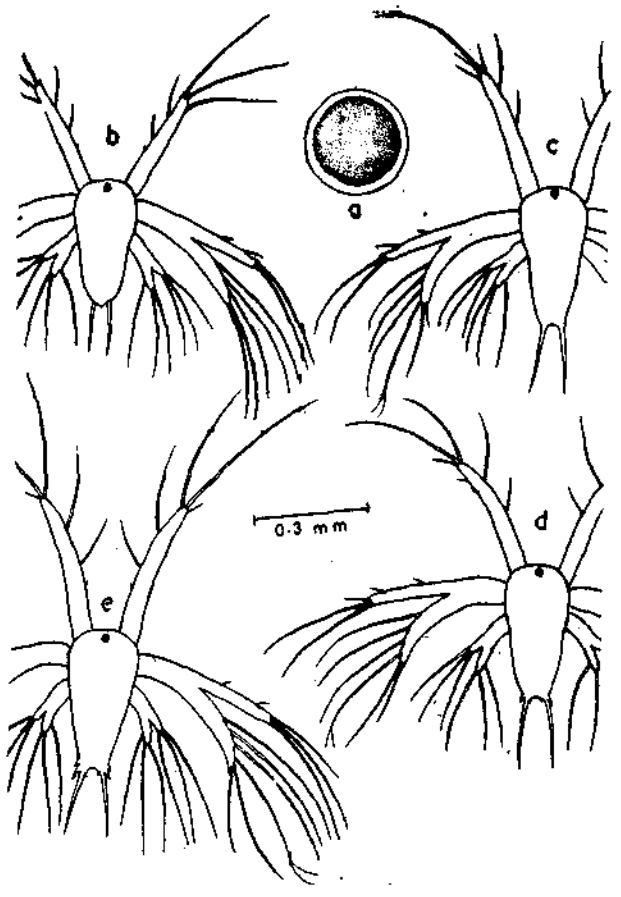

Fig. 1 *Penaeus semisulcatus:* a - egg; b - Nauplius I; c - Nauplius II; d - Nauplius III; e - Nauplius IV.

bearing 3 long setae terminally; setae on all appendages nonplumose. Duration of this substage was 5½ hours.

NAUPLIUS II

MTL: 0.33 mm (0.31-0.34 mm); MW: 0.17 mm: MFS: 0.16 mm (0.14-0.17 mm).

Setae on all appendages plumose; 1+1 furcal setae., A1 with 3 distal setae of which 1 is long, 1 distolateral and 2 inner lateral setae; A2 with 1 short seta added terminally in exopod, 4th seta from proximal end with bifurcated tip, a feature which is retained in all subsequent nauplius substages (Fig.1,c). Duration of this substage was 4 hours.

NAUPLIUS III

MTL: 0.34 mm (0.32-0.35 mm); MW: 0.17 mm (0.17 mm-0.18 mm); MFS: 0.20 mm(0.17-0.21 mm).

Posterior margin of body with 3+3 furcal setae (Fig.1,d); distally A1 bears 3 setae, of which 1 is small, a small distolateral seta present in some specimens, of the 2 inner lateral setae, distal one is longer; endopod of A2 with 3 distal and 2 lateral setae; exopod with 6 long setae. Duration of this substage was 4 hours.

NAUPLIUS IV

MTL: 0.34 mm (0.32-0.35 mm); MW: 0.17 mm (0.17-0.18 mm);. MFS: 0.20mm (0.18-0.21mm).

4+4 furcal setae; 1 short proximal seta added to inner lateral margin of A1; endopod of A2 with 3 long distal and 2 short ventrolateral setae, exopod with 6 long setae and 1 short seta (Fig.1,e); base of Md slightly swollen, small buds of Mx and Mxp seen developing behind Md. Duration of this substage was 6 hours.

NAUPLIUS V

MTL: 0.39 mm (0.38-0.39 mm); MW: 0.18 mm (0.17-0.18mm);MFS: 0.26 mm (0.24-0.27 mm).

Furcal lobes with 6+6 setae (Fig.2,a); A1 without change; endopod of A2 with 3 long setae and 1 small seta distally and 2 inner lateral setae, exopod with 7 long and 2 short setae. Duration of this substage was 6 hours.

NAUPLIUS VI

MTL: 0.46 mm (0.42-0.49 mm): MW: 0.18 mm (0.17-0.18 mm);MFS: 0.31 mm (0.29-0.32 mm)

Outline of the developing carapace clearly seen (Fig.2,b), caudal furcae with 7+7 setae; partial segmentation seen on A1 and A2; buds of Mx and Mxp further developed; A1 with 1 short and 2 long setae terminally and 3 setae on inner lateral margin, of which distal one very long, 2 distolateral setae added on outer margin; endopod of A2 with 4 distal and 2 inner lateral setae, exopod with 11 setae of which 2 small; swelling at base of Md

(Fig.2,c) prominent. Duration of this substage was 16 hours.

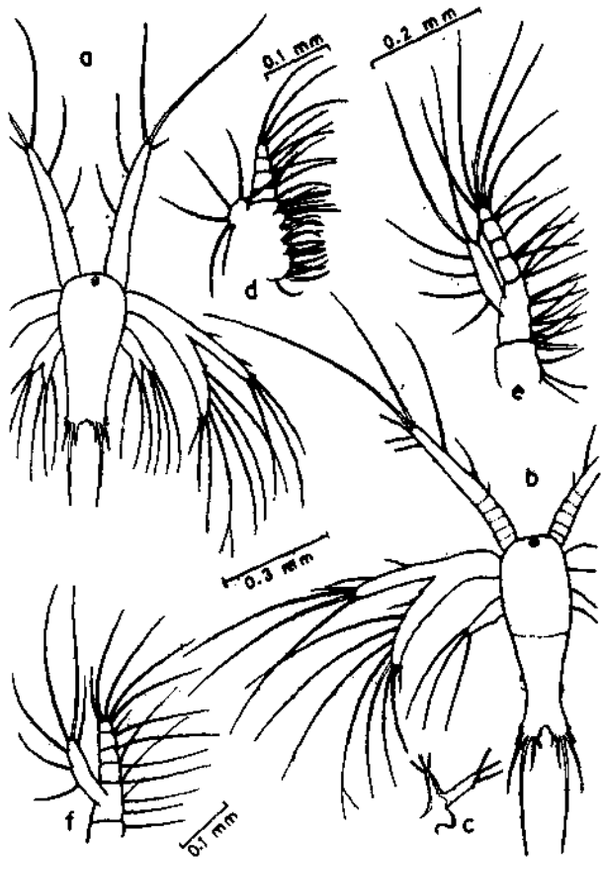

Fig. 2 *Penaeus semisulcatus:* a - Nauplius V; b - Nauplius VI; c - Md of Nauplius VI; Protozoea I: d - Mx2; e - Mxp1; f - Mxp2.

PROTOZOEA I

MTL: 0.96 mm (0.95-0.98 mm); MCL: 0.44 mm (0.42 -0.47 mm).

Carapace rounded anteriorly with median concavity (Fig.3,a) and 2 small rounded frontal organs, naupliar eye persists, developing compound eyes covered by carapace, thorax 6 segmented, abdomen unsegmented, telson not demarcated from abdominal segment, each lobe of telson with 7 setae, of which outermost one shortest originating from dorsolateral aspect of telson.

A1 (Fig.3,a) with 3 segments, basal segment with 5 indistinct divisions, 2nd segment bears 3 setae on inner side, distal segment with 2 aesthaetes and 3 setae of which one is more than twice length of A1; A2 (Fig.3,a) 2segmented, endopod with 5 terminal setae of which inner one very small, and 1+1+2 inner lateral setae, exopod 10 segmented, with 11 plumose setae along inner and distal margin and 2 on outer margin; Md (Fig.3,b) exopod and endopod absent, incisor

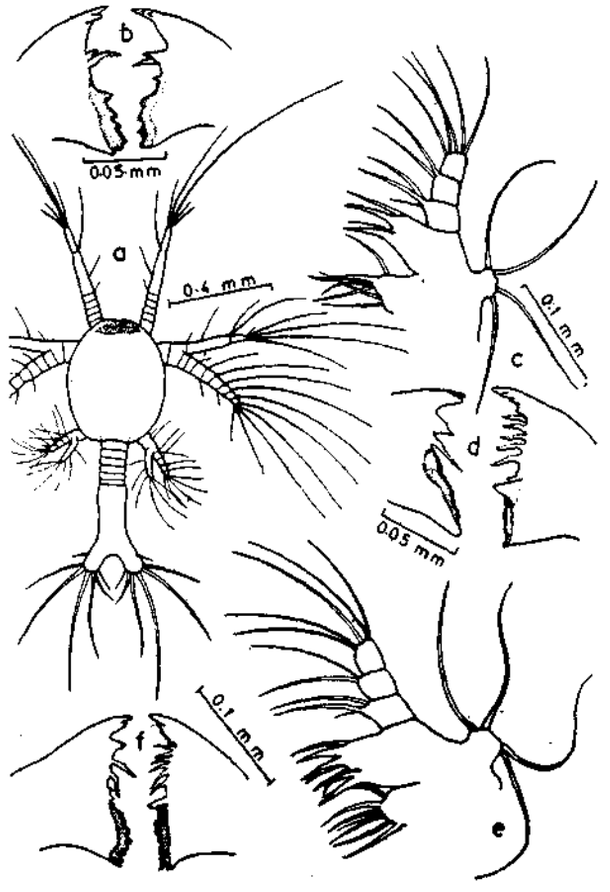

Fig. 3 *Penaeus semisulcatus:* Protozoea I: a - dorsal view; b - Md; c - Mx1; Protozoea II: d - Md; e - Mx1; Protozoea III: f - Md.

process with 3 teeth and molar with a number of transverse rows of small grinding teeth, 1 serrated tooth and a shorter tooth present in between molar and incisor processes, Mx1 (Fig.3,c) exopod small, knob-like, bearing 4 long feathery setae, endopod 3 seamented bearing 5, 2, 3 setae respectively on distal, middle and proximal segments, distal endite with 4 stout setae and proximal with 6 setae; Mx2 (Fig.2,d) exopod knob-like with 5 long feathery setae, endopod 3 segmented, middle segment showing a partial division, distal segment carries 3 setae and other segments with 2 long setae on inner distal margin,

protopod with 5 endites, proximal one semicircular bearing 7 to 8 setae, other endites with 4 to 5 setae; Mxp1 (Fig.2,e) biramous, exopod unsegmented with 7 plumose setae, endopod 4 segmented with 5 long setae on distal segment, 1st, 2nd and 3rd segments with 3, 1 and 2 setae respectively on inner side, protopod 2 jointed, basis with 12 and coxa with 5 setae on inner side; Mxp2 (Fig.2,f) shorter than Mxp1, exopod unsegmented with 6 long plumose setae of which 3 are outer, 2 terminal and 1 inner distal, endopod 4 segmented, 1st, 2nd, 3rd and 4th segments with 2, 1, 2 and 5 setae respectively, basis with 5 setae; Mxp3 absent. Duration of this substage was 50 hours.

PROTOZOEA II

MTL: 1.74 mm (1.61-1.85 mm); MCL: 0.70 mm (0.67-0.73 mm).

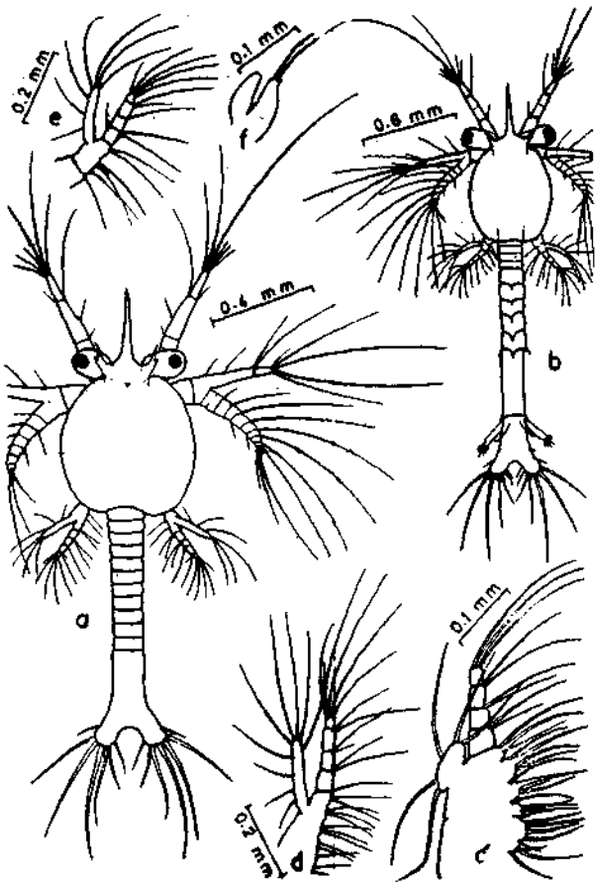

Fig. 4 *Penaeus semisulcatus:* Protozoea II: a - dorsal view; Protozoea III: b - dorsal view; c - Mx2; d - Mxp1; e Mxp2; f - Mxp3.

Major changes from protozoea I are the development of stalked compound eyes, rostrum, bifurcated supraorbital spines and 6 segmented abdomen (Fig.4, a).

A1 distal segment with 3 setae and 3 aesthaetes; A2 same as in the previous stage; Md (Fig. 3,d) asymmetrical, left Md with 5 and right with 1 free standing teeth; Mx1 (Fig.3,e proximal and distal endites each with 7 to 8 setae; no appreciable change in Mxp1 and Mxp2. Duration of this substage was 60 hours.

PROTOZOEA III

MTL: 2.47 mm (2.41-2.57 mm); MCL: 0.87 mm (0.84-0.91 mm).

Supraorbital spine simple, telson demarcated from last abdominal segment by articulating joint, dorsomedian spine present on posterior border of first 5 abdominal segments, 5th and 6th abdominal segments with a pair of posterolateral spines; biramous buds of Mxp3 and uropods develop and telson with 8 + 8 setae (Fig. 4,b).

Subdivisions on basal segment of A1 disappear, distal segment with 3 setae and 4 aesthaetes; Md (Fig.3,f) left Md with 6 free standing teeth and right with 2; Mx1, no appreciable change; Mx2 (Fig.4,c) number of setae on endites increased; Mxp1 (Fig.4,d) exopod with 9 plumose setae, 1 seta added to 2nd segment of endopod; Mxp2 (Fig.4,e) exopod with 7 setae, 1st segment of endopod with 1 seta on outer margin; Mxp3 (Fig.4,f) biramous, with 2 setae and a small setal rudiment at distal end of one ramus. Duration of this substage was 44 hours.

MYSIS I

MTL: 3.15 mm (2.99 - 3.29 mm); MCL: 1.10 mm (1.00-1.15 mm).

Rostrum long, extending beyond eye and devoid of spines (Fig.5,a); carapace with hepatic, supraorbital and pterygostomial spines; P1 to P5 developed and functional; 4th, 5th and 6th abdominal segments with dorsal spine on posterior margin, 5th and 6th with a pair of lateral spines and 6th in addition bears a ventromedian curved

spine at junction with telson; uropod biramous (Fig. 5, k), exopod with 14 plumose setae, a prominent posterolateral spine on outer border and a short non-plumose seta between the posterolateral fixed spine and the plumose setae, endopod with 13 plumose setae along inner and

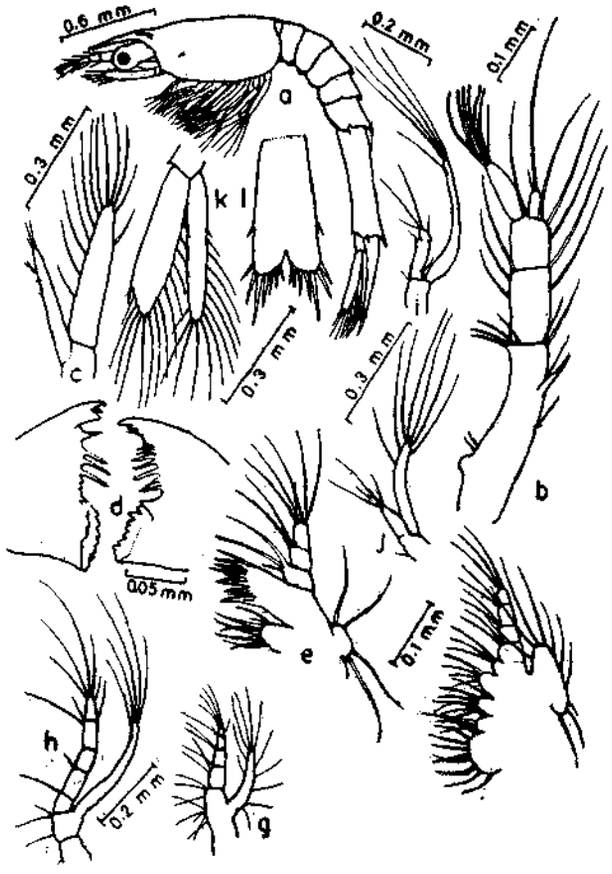

Fig. 5 *Penaeus semisulcatus:* Mysis I: a - lateral view; b - A1; c - A2; d - Md; e - Mx1; f - Mx2; g - Mxp1; h - Mxp3; i - P1; j - P4; k - uropod; l - telson.

distal margin, telson (Fig. 5,l) broader distally with median notch, each lobe with 1 lateral and 7 terminal setae.

A1 (Fig. 5,b) 3 segmented, basal segment with anteromedian spine and 2 setae above stylocerite rudiment, distal segment with 2 flagellar rudiments, outer rudiment with 6 aesthaetes and 1 seta, inner only half size of outer, bearing 1 long and 1 short seta terminally; A2 (Fig. 5,c) exopod unsegmented, leaf like with a distolateral seta on outer margin and 11 setae along inner and distal margin, endopod unsegmented carrying 3 terminal seta and 2 distolateral setae placed on a minute projection; Md (Fig. 5, d) asymmetrical, right and left Md with 3 and 7 free standing teeth respectively between incisor and molar processes; Mx1 (Fig. 5, e) distal and proximal endites with 11 and 8 setae respectively, knob-like exopod with 4 long feathery setae; Mx2 (Fig. 5, f) exopod expanded to form scaphognathite, with 10 plumose setae; Mxp1 (Fig. 5, g) exopod with 11 plumose setae, 1 seta added to 1st segment of endopod along outer margin; Mxp2 basis with 7 setae on inner side, exopod with 6 long plumose setae distally, endopod 4 segmented, terminal segment with 5 long setae; Mxp3 [Fig.5,h] biramous, coxa and basis bearing 1 and 3 setae on inner side respectively, exopod as long as endopod bearing 4 aptcal and 2 subapical plumose setae, endopod 5 segmented, terminal segment with 5 setae, 1st, 2nd and 4th segments bearing 1, 1, 3 setae respectively, 3rd segment without any seta; P1 to P3 almost identical (Fig 5, i) endopod unsegmented, developing chela seen with 5 terminal setae, exopod longer than endopod bearing 4 apical and 3-4 subapical long plumose setae; P4 and P5 identical (Fig.5,j) endopod unsegmented, half length of exopod, bearing 4 apical setae, exopod with 7 to 8 long plumose setae distally. Duration of this substage was 22 hours.

MYSIS II

MTL: 3 50 mm (3.48 - 3.52 mm); MCL: 1.13 mm (1.10-1·16 mm).

Rostrum extending to tip of eye or slightly beyond, devoid of any spine (Fig.6,a), carapace with spination as in the previous substage; exopod of uropod (Fig.6,h) with 16 plumose setae and 1 non-plumose seta (Fig.6, i) in addition to posterolateral fixed spine, endopod with 14 plumose setae; telson (Fig.6,j) almost rectangular, middle cleft extending to level of origin of penultimate lateral setae, telson with 2 pairs of lateral and 6 pairs of distal setae.

A1 (Fig.6,b) number of setae on A1 segments increased, basal segment with swollen base showing the developing statocyst and carries 3 plumose short setae; A2 (Fig.6,c) exopod with 18 plumose setae along inner and distal margin, a spine replaces the seta on distolateral outer margin, endopod unsegmented and devoid of setae; Md (Fig.6,d) unsegmented, small palp developed; Mx1, except for absence

of exopod no other change in appendage; Mxp2 (Fig.6,e) endopod 5 segmented, distal segment with 6 long setae, 1st, and 2nd segments carry 1 seta each on outer distal margin; Mxp3, 3rd segment of endopod with 2 setae; p1 to p3

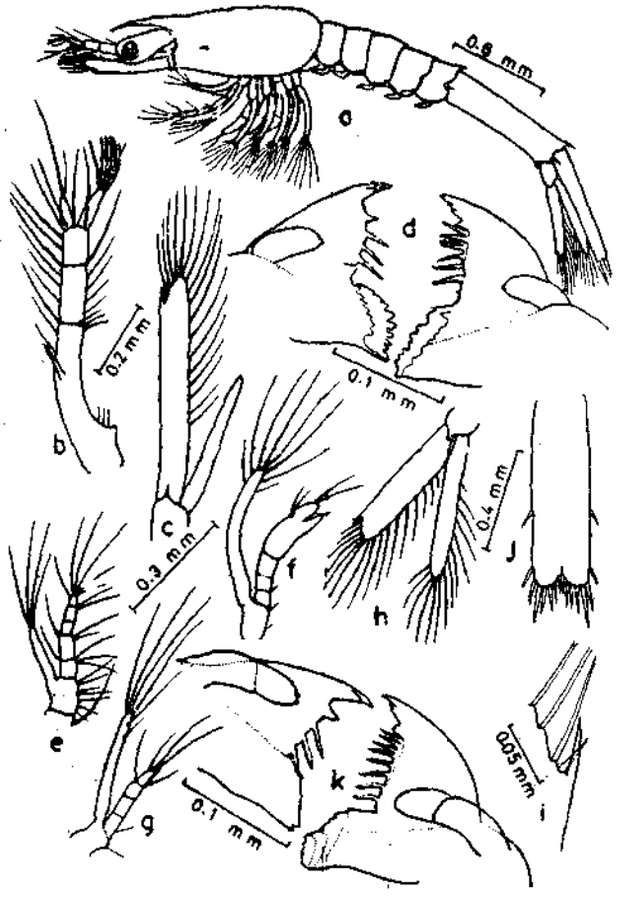

Fig. 6 *Penaeus semisulcatus:* Mysis II: a - lateral view; b - A1; c - A2; d - Md; e - Mxp2; f - P1; g - P5; h - uropod; i - distolateral tip of exopod of uropod; j - telson. Mysis III: k - Md.

almost identical (Fig.6,f) endopod 4 segmented, chela developed bearing 5 setae, exopod almost of same size as endopod, bearing7-8 long setae distally; p4 and p5 (Fig.6,g) similar, endopod 4 segmented, 3rd and 4th segments bearing 2 and 3 setae respectively. Duration of this substage was 56 hours.

MYSIS III

MTL: 4.43 mm (4.38-4.48 mm); MCL; 1.50 mm (1.48 - 1.51 mm).

Rostrum extends beyond eye (Fig.7,a), in some specimens a rudimentary rostral tooth may be present, supraorbital, hepatic and pterygostomial spines present; pleopods 2 segmented; exopod and endopod of uropod with 19 and 23 setae respectively (Fig. 7,f), median cleft of telson (Fig.7,g) reduced.

A1(Fig.7,b) statocyst seen at base of 1st segment, flagella of equal size, outer flagellum 2 segmented with 7 aesthaetes in 3 groups of 3 + 2+2 and 2 terminal seta, inner flagellum indistintctly 2 segmented with 4 apical setae; A2 (Fig.7,c) exopod with 22 plumose setae and 1 outer lateral spine, endopod 2 segmented bear-

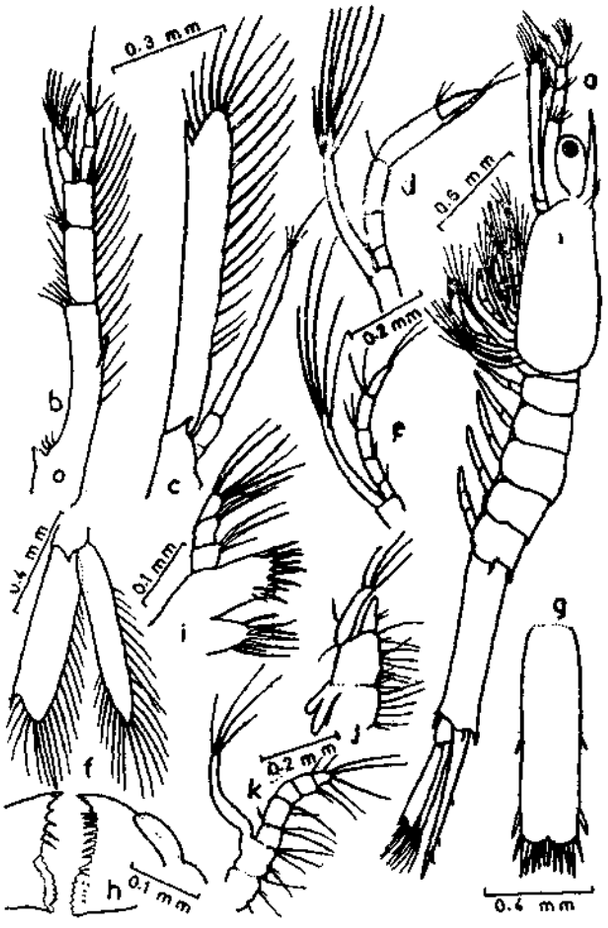

Fig. 7 *Penaeus semisulcatus:* Mysis III: a - lateral view; b - A1; c - A2; d - P1; e - P5; f - uropod; g - telsou. Intermediate stage: h - Md; i - Mx1; j - Mxp1; k - Mxp2;

ing 4 apical setae; Md (Fig.6,k)palp 2 segmented but devoid of setae; Mx1 no change from previous stage; Mxp2 rudiment of gill developed, exopod bears 4 long plumose setae apically; Mxp3 rudimentary gills present on coxa,

endopod longer than exopod and 5 segmented, distal segment with 4 setae; P1 to P3, although identical in appearance, show progressive increase in size from P1 to P3 (Fig.7,d) rudimentary gills developed, endopod 5 segmented, chela fully developed and dactylus with 2 apical setae; P4 and P5 (Fig.7,e) identical, endopod 5 segmented, 3rd and 5th segments each bearing 2 distal setae. Duration of this substage was 18 hours.

INTERMEDIATE STAGE

MTL: 4.21 mm; MCL: 1.26 mm

Although pleopods (Fig.8,g) bear 5 short terminal setae, exopods of pereopods retain apical setae; spines on carapace, abdomen and telson same as in mysis stage (Fig.8,a),

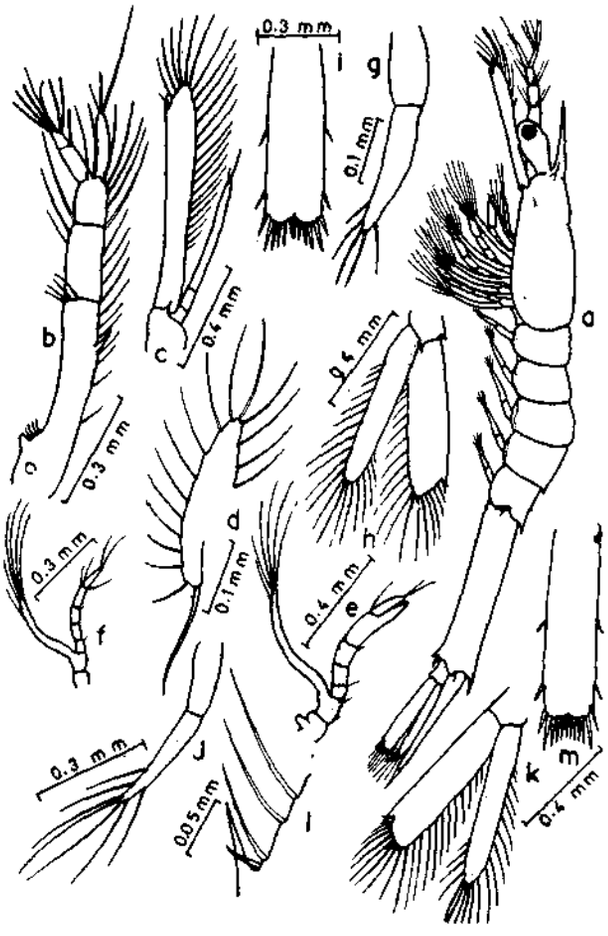

Fig 8 *Penaeus semisulcatus:* Intermediate stage: a - lateral view; b - A1; c - A2; d - exopod of Mx2; e - P1; f - P5; g - pleopod; h - uropod; i - telson. Postlarva I: j - pleopod; k - uropod; l - distolateral tip of exopod of uropod; m - telson.

exopod of uropod with 18 plumose setae and 1 non-plumose seta in addition to distolateral fixed spine (Fig.8,h), endopod with 20 plumose setae; telson (Fig.8,i) truncate with 5 pairs of distal and 3 pairs of lateral setae.

A1 (Fig.8,b) statocyst fully developed, number of setae on segments increase, flagella almost equal in size, outer with 7 to 8 aesthaetes and 1 seta, inner with 3 setae apically; A2 (Fig.8,c) exopod with 24 plumose setae and 1 distolateral spine, endopod with 2 clear segments and 2 indistinct segmentation, more than half length of exopod and beset with 2 apical setae; Md (Fig.7,h) and Mx1 (Fig.7,i) without any noticeable change; Mx2 (Fig.8,d) exopod with 16 plumose setae; Mxp1 (Fig.7,j) endopod and exopod reduced in size, protopod segments enlarged, gill rudiments well developed, endopod unsegmented bearing only 2 small setae on inner side, exopod with 6 setae; Mxp2 (Fig.7,k) endopod 5 segmented with a slight bent towards inner side, length of setae slightly reduced; Mxp3 without any noticeable change; P1 to P5 (Fig.e,f) rudimentary gill developed.

POSTLARVA I

MTL: 4.82 mm (4.76 - 4.87 mm); MCL: 1.50 mm (1.47 - 1.54 mm).

Rostrum longer than eye, bearing 1 dorsal spine (Fig.9,a), supraorbital, pterygostomial and hepatic spines present; 4th, 5th and 6th abdominal segments with a posteromedian dorsal spine, lateral spine present on 5th and 6th abdominal segments, anal spine persits, exopods of pereopod rudimentary, pleopods (Fig.8,j) fully developed bearing 3 to 4 pairs of plumose setae; telson (Fig.8,m) with 5 pairs of distal and 3 pairs of lateral setae; exopod of uropod (Fig.8,k,l) with 21 plumose setae and 2 short nonplumose setae, endopod with 20 plumose setae.

A1 (Fig.9,b) basal segment with well developed statocyst, ventromedian spine persists, outer flagellum 2 segmented carrying 8 aesthaetes in 3 groups of 4+2+2, apically 2 slender setae present, inner flagellum longer than outer, 3 segmented with 3 apical setae; A2 (Fig.9,c) scale with 22 long plumose setae and 1 distolateral spine, endopod 5

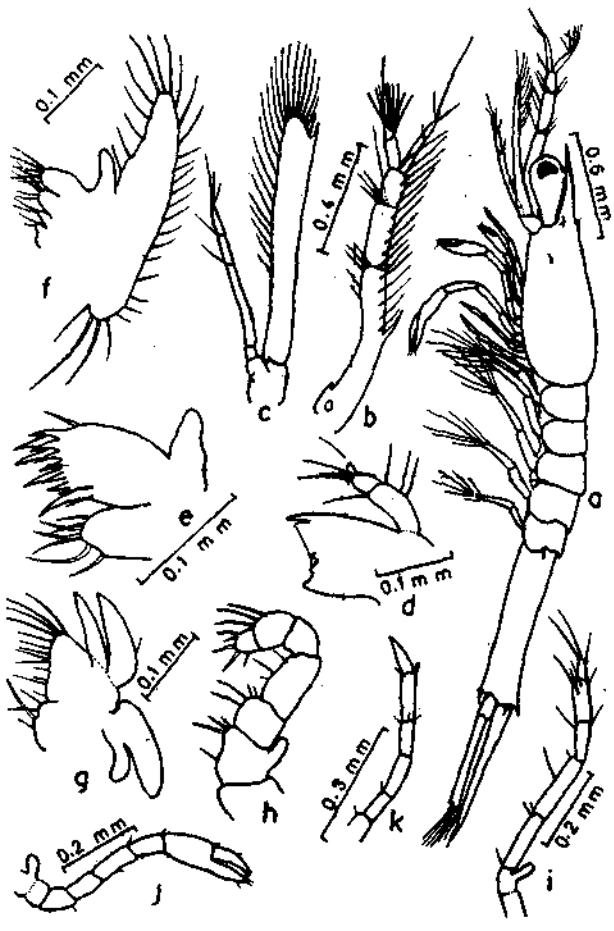

Fig. 9 *Penaeus semisulcatus:* Postlarva 1: a - lateral view; b - A1; c - A2; d - Md; e - Mx1; f - Mx2; g - Mxp1; h - Mxp2; i - Mxp3; j - P1; k - P5.

segmented, almost same length as exopod; Md (Fig.9,d) symmetrical, standing teeth lacking, palp 2 segmented, proximal segment with 3 setae on outer margin, 1 seta on distal inner border and distal segment with 3 apical setae; Mx1 (Fig.9,e) endopod rudimentary, unsegmented and without setae, distal lobe longer than proximal and bears 13 setae, proximal lobe with 7 to 8 setae. Mx2 (Fig.9,f) 4 endites much reduced in size, proximal 2 endites each bearing 2 setae, distal 2 endites with 4 to 6 setae, endopod unsegmented and much reduced, exopod fairly large bearing 28 plumose setae; Mxp1 (Fig,9,g) endopod and exopod unsegmented and much reduced, gills fully developed, protopod broad carrying numerous setae; Mxp2 (Fig. 9,h) acquires typical adult shape, exopod vestigial, endopod recurved, distal segment with 5 stout setae, 4th segment with 3 long setae, first 2 segments with 4 and 3 setae respectively; Mxp3 (Fig.9, i) protopod with gills, exopod vestigial, endopod 5 segmented, distal 2 segments with 3 to 4 long setae; P1 to P3 (Fig. 9, j) rudimentary gill present, exopod absent or highly reduced and without setae; P3 longest, chela fully developed, tips beset with small brushlike setae; P4 and P5 (Fig. 9, k) identical, exopod absent, endopod 5 segmented without many long setae.

REMARKS

Although *P. semisulcatus* has been reared from the egg to the juvenile stage under controlled conditions in Taiwan (Liao and

	P. semisulcatus (present material)	*P. semisulcatus* (Liao and Huang[1])
Egg	0.28 mm	0.26 mm
Nauplius I	0.30 ,,	.....
Nauplius II	0.33 ,,	.....
Nauplius III	0.34 ,,	.....
Nauplius IV	0.34 ,,	.....
Nauplius V	0.39 ,,	.....
Nauplius VI	0.46 ,,	0.53
Protozoea I	0.96 ,,	1.02
Protozoea II	1.74 ,,	.....
Protozoea III	2.47 ,,	2.71
Mysis I	3.15 ,,	3.38
Mysis II	3.50 ,,	.....
Mysis III	4.43 ,,	4.74
Postlarva I	4.82 ,,	5.22

Huang[1]) only the length of some larval stages is given by them. The detailed structure of the various larval stages is described for the first time in this paper. The egg diameter and the length of the larvae of *P. semisulcatus* from India (present material) and Taiwan (Liao and Huang[1]) are compared in the preceding table.

Although the present eggs are slightly larger than those from Taiwan, all the larval stages from Taiwan were a little larger than the corresponding stages in the present material.

In addition to the 6 nauplius, 3 protozoea and 3 mysis substages, some times an intermediate substage between the last mysis and postlarva I was also observed during the present study. In the intermediate stage the pleopods have setae but the exopods of the pereopods remain fully functional and the Md, Mx1, Mx2, Mxp1 and Mxp2 retain the mysis stage characters The specimens in the intermediate stage were however very rare.

V

Larval development — *METAPENAEUS DOBSONI* (MIERS)

M. S. Muthu
N. N. Pillai
K. V. George

Complete larval history of *Metapenaeus dobsoni* was studied by rearing them in the laboratory. At the rearing temperature of 25.5°C to 26.8°C the viable eggs took 16-17 hours to hatch; the duration of the nauplius stage was 40-56 hours; protozoea took 5-7 days to reach the mysis stage and the mysis transformed into postlarva I after 6-9 days. Thus it took 14-20 days for the eggs to develop through the various larval stages into postlarva I. The larvae pass through 6 nauplius substages, 3 protozoea substages and 5 mysis substages before reaching the postlarval stage. There may be one or two intermediate substages between the last mysis substage and postlarva I. All the larval stages are described and illustrated, and compared with the earlier larval descriptions of the species.

At the Narakkal prawn culture laboratory of the Central Marine Fisheries Research Institute, *Metapenaeus dobsoni*, the most abundant species of penaeid prawn on the south west coast of India, has spawned on many occasions and the eggs have been reared up on a large scale to the stocking size. The larval stages of *M.dobsoni* have been described by earlier workers, Menon (1951, *Proc. Indo-Pacif-Fish Coun.* 3rd meeting, Sec II: 80-93[1]), Rao and Kathirvel (1973, *Indian J.Fish*, 20 (1): 228-230[2]), Rao (1974, *J.mar. biol. Ass. India* 15 (1): 95-124[3]), and Thomas et al. (1974, *Indian J.Fish.* 21 (2): 575-579[4]). But, a routine examination of the larvae reared at Narakkal revealed a number of interesting morphological features which had been overlooked by these authors The setation of the appendages which is of great taxonomic value in the identification of the penaeid larvae was in particular not fully described by the earlier authors. It was also found that *M. dobsoni* passes through more number of mysis substages than hitherto recorded. Hence a description of the eggs and the various larval stages is presented here. The temperature of the water in the rearing tanks varied from 25.5° C to 26.8° C and the salinity from 30.2 to 35.2 ‰.

The authors are grateful to Dr. E. G Silas, Director, Central Marine Fisheries Research Institute, for the encouragement and facilities provided and for his valuable suggestions.

DESCRIPTION OF DEVELOPMENTAL STAGES

EGGS

The eggs are opaque with a very wide perivitelline space (Fig.1,a), diameter of the egg and yolk mass varied from 0.35 to 0.41 mm and 0.20 to 0.22 mm respectively, the freshly spawned eggs of *M.dobsoni* do not have any radiating jelly-like substance seen in the case of *Penaeus indicus*. Embryonic development takes 16-17 hours.

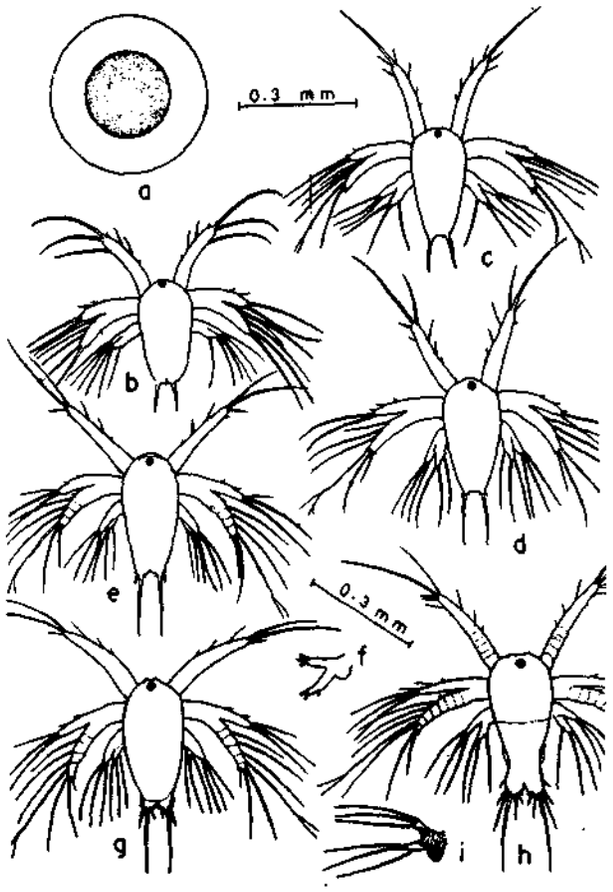

Fig. 1 *Metapenaeus dobsoni;* a - egg; b - Nauplius I; c - Nauplius II; d - Nauplius III; e - Nauplius IV; f - Md of Nauplius IV; g - Nauplius V; h - Nauplius VI; i - Md of Nauplius VI.

NAUPLIUS I

MTL: 0.26 mm (0.25-0.28 mm); MW: 0.14 mm (0.14-0.15 mm);MFS: 0.08 mm (0.07-0.10 mm).

Furcal setae 1+1; minute posterodorsal tooth present; setae nonplumose; A1 with 3 short lateral setae on inner margin, 2 long setae and 1 spike-like seta terminally and 1 long seta on outer distal margin; exopod of A2 with 5 long setae along inner and distal margin, endopod with 2 short lateral setae on inner margin and 2 long setae and a rudimentary seta terminally; Md with 3 distal setae on exopod and endopod (Fig.1,b). Duration of this substage was 3-4 hours.

NAUPLIUS II

MTL: 0.27 mm (0.26-0.28 mm); MW: 0.15 mm (0.14-0.15 mm); MFS: 0.08 mm (0.07-0.10 mm).

Furcal setae 1+1; posterodorsal tooth absent; setae plumose; the spike-like terminal seta of A1 has become a short seta while long outer terminal and outer lateral setae have become short (Fig.1,c); exopod of A2 with a minute seta added to outer terminal end, 4th seta from proximal end bifurcate, with a characteristic bend proximal to split, this condition of the seta is retained in all nauplius substages; no change in Md. Duration of this substage was 3-4 hours.

NAUPLIUS III

MTL: 0.29mm (0.28-0.29mm); MW: 0.15mm (0.14-0.15mm); MFS: 0.12mm (0.11-0.14mm).

Furcal setae 3+3 (Fig. 1,d); inner terminal seta of A1 longer than outer; exopod of A2 with 6 long and one rudimentary seta. Duration of this substage was 5-8 hours.

NAUPLIUS IV

MTL: 0.31 mm (0.29-0.32 mm); MW: 0.15 mm (0.15-0.16 mm); MFS: 0.13 mm (0.10-0.14 mm).

Furcal setae 4+4 (Fig. 1,e); developing frontal organs and buds of mouth parts seen; distolateral outer seta of A1 very thin and short, inner terminal seta longer than in previous substage; exopod of A2 with faint segmentation, 1 rudimentary seta added to inner lateral margin proximally, endopod with one short and 2 long setae terminally; Md with a swelling at base (Fig.1,f). Duration of this substage was 3-4 hours.

NAUPLIUS V

MTL: 0.33 mm (0.32-0.34 mm): MW: 0.15 mm (0.14-0.15 mm); MFS: 0.17 mm (0.15-0.18 mm).

Furcal setae 6+6 (Fig.1,g); frontal organs prominent; outer lateral seta in A1 lost; exopod of A2 with 9 setae, the proximal and terminal ones rudimentary; swelling at base of Md enlarged. Duration of this substage was 10-12 hours.

NAUPLIUS VI

MTL: 0.35mm(0.35-0.36mm); MW: 0.15 mm (0.15-0.17 mm); MFS: 0 17 mm (0.16-0.18mm).

Furcal setae 7+7 (Fig.1,h); A1 with 1 short additional terminal seta, 2 setae, 1 short and 1 minute added to outer lateral margin in distal half, indistinct segmentation in proximal half; exopod of A2 with 9 setae, endopod with 1 short and 3 long setae apically; cutting edge of Md visible inside basal swelling, exopod and endopod usually empty (Fig.1, i). Duration of this substage was 16-24 hours.

PROTOZOEA I

MCL: 0.33 mm (0.32-0.34 mm); MTL: 0.76 mm 0.73-0.77 mm).

Frontal organs overhung by frontal horns (Fig.2, a) telson with 7 setae on each furcal lobe.

A1 (Fig. 2,b) with 3 main segments, the proximal one subsdivided into 5 subsegments, basal segment with 1 distal seta on inner margin, middle segment with 2 distal setae, 1 long and 1 very short, and 1 short lateral seta in the middle, distal segment bears terminally an aesthaetes and 3 setae of which 1 is very long, and a subterminal aesthaetes; A2 (Fig.2,c) exopod 10 segmented, bearing 10 long setae along inner and distal margin and 2 short setae on outer margin, endopod 2-segmented, distal segment tipped with 4 long plumose setae and 1 short nonplumose seta, basal segment with 1+2+3 nonplumose setae on inner margin;Md (Fig.2,d) almost symmetrical with 1 serrated free standing tooth between incisor and molar processes; Mx1 (Fig.2,e) protopod with 2 endites, distal one with 4 stout setae and proximal with 7 setae, exopod with 4 long feathery setae, endopod 3 segmented, distal segment with 5 long terminal setae, middle segment with 2 setae and proximal with 3 setae of which 1 is small; Mx2 (Fig. 2, f) protopod with 5 endites, basal one with 8 setae and the rest with 3 to 4 setae, exopod with 5 long feathery setae, endopod 4 segmented, the segmentation between 2nd and 3rd segments indistinct, the distal one with 3 terminal setae and the rest with 2 setae

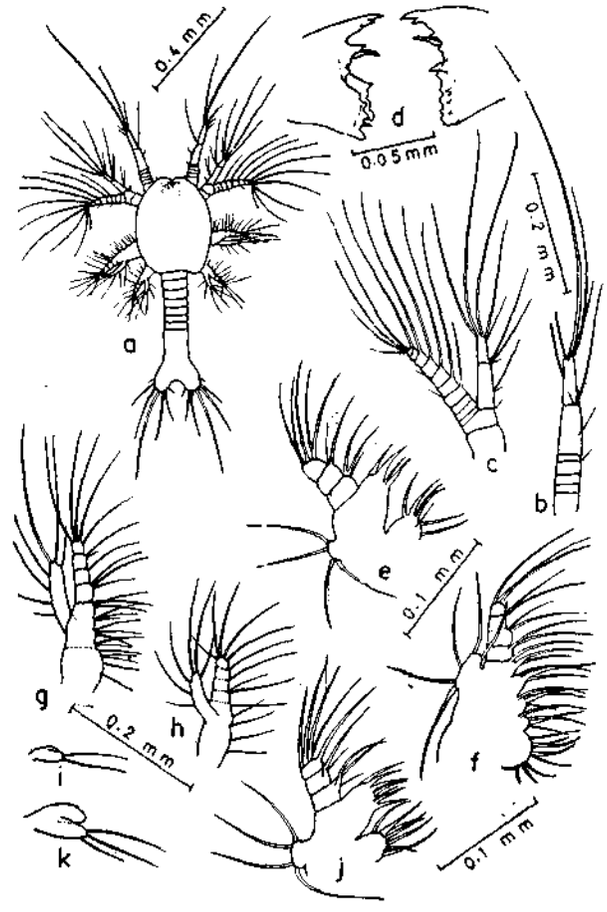

Fig. 2 *Metapenaeus dobsoni:* Protozoea I: a - dorsal view; b - A1; c - A2; d - Md; e - Mx1; f - Mx2; g - Mxp1; h - Mxp2; i - Mxp3. Protozea II: j - Mx1; k - Mxp3.

each; Mxp1 (Fig.2, g) protopod indistinctly divided into 2 segments, distal one bearing 11 to 12 setae and the proximal one 4 to 5 setae, endopod 4 segmented, 1st segment with 3 setae, 2nd with 1 and 3rd with 2 and distal with 5 setae, exopod unsegmented with 7 setae; Mxp2 (Fig.2,h) endopod indistinctly divided into 4 segments, 1st segment with 2 setae, 2nd and 3rd with 1 each and distal with 5 setae, exopod with 6 setae, protopod with 5 setae; Mxp3 (Fig.2,i) biramous rudiment with 2 setae on exopod; Duration of this substage was 36 to 48 hours.

PROTOZOEA II

MCL: 0.45 mm (0.43-0.46 mm); MTL: 1.21 mm (1.15-1.30mm).

Eyes stalked; carapace with rostrum and 2 supraorbital spines (Fig.3,a); telson bears 7 setae on each furcal lobe; A1 (Fig.3,b) with some hair like setae added to middle segment on outer distal margin; A2 (Fig.3,c), shortest of 5 terminal setae on endopod has become plumose, out of 6 lateral setae 3 longer ones

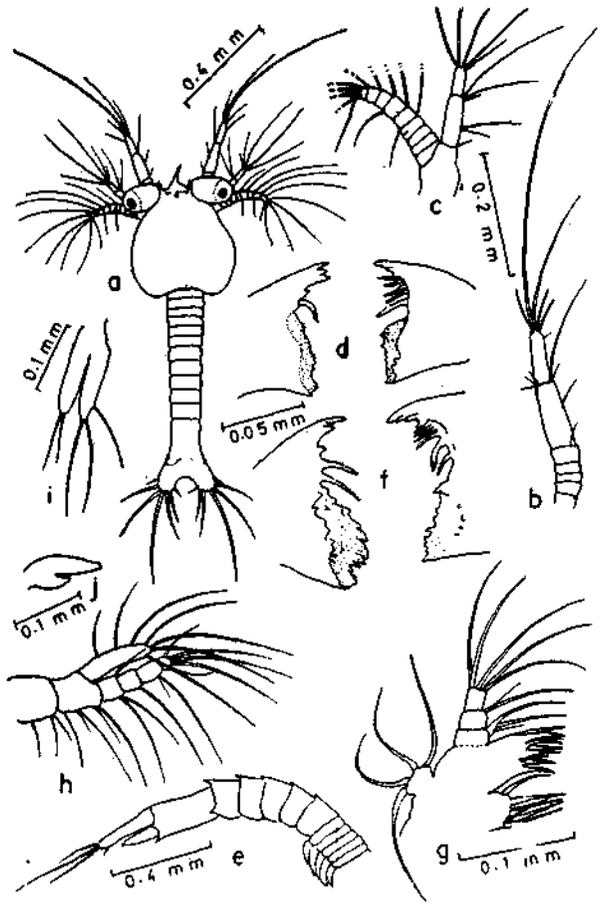

Fig. 3 *Metapenaeus dobsoni:* Protozcea II; a - dorsal view; b - A1; c - A2; d - Md. Protozoea III: e - lateral vaew of abdomen and telson: f - Md: g - Mx1: h - Mxp2: i - Mxp3: j - pereiopods bud.

plumose; Md (Fig.3,d) asymmetrical, left with 5 free standing teeth and right with 1 free standing tooth; Mx1 (Fig.2,j) distal endite with 7 setae; Mx2, more setae added to endites Mxp1, antepenultimate segment of endopod with 1 more additional seta; Mxp3 (Fig 2,k) exopod rudiment with 3 setae. Duration of this substage was 48 to 72 hours.

PROTOZOEA III

MCL: 0.58 mm (0.56-0.64 mm); MTL: 1.61 mm (1.48-1.75 mm).

Rostrum prominent, supraorbital spines reduced in size (Fig.4, a); thoracic segments bear biramous pereopod buds (Fig.3,e,j); abdominal segments 1 to 5 with posterodorsal spines (Fig.3,e), 5th segment with posterolateral spine on each side,with posterolateral spine on each side, 6th segment demarcated from telson, lacks dorsomedian spine but has a minute pair of

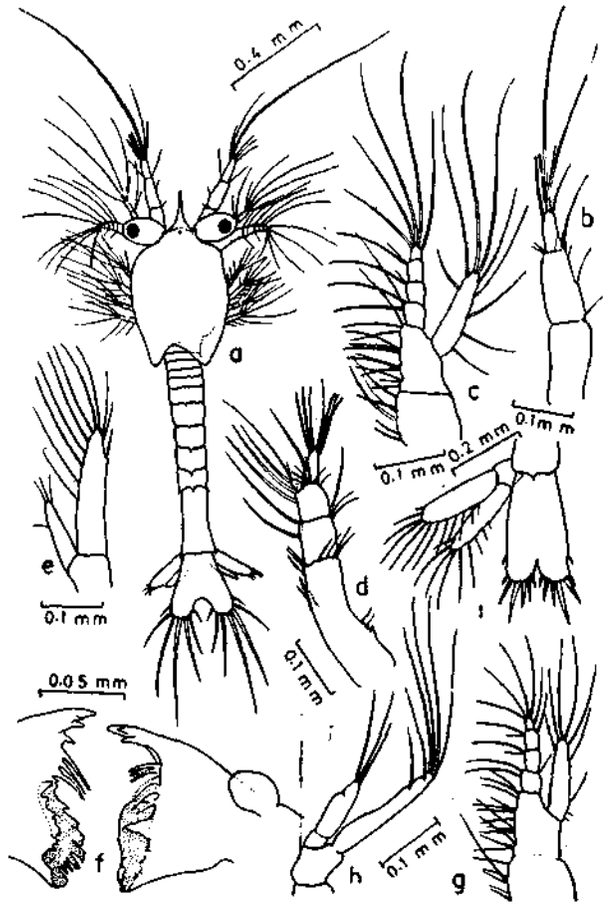

Fig. 4. *Metapenaeus dobsoni:* Protozoea III: a - dorsal view; b - A1; c - Mxp1; Mysis I: d - A1; e - A2; f - Md; g - Mxp1; h - P2; i - uropod & telson.

posterolateral and a pair of ventrolateral spines; uropod rudiments formed, outer ramus tipped with 5 small setae; telson with 7 setae on each furcal lobe.

Al (Fig.4,b) 5 subsegments of basal segment fused into one unit, more hair like setae added to distal margin of middle segment, 1 slender terminal seta added to distal segment; Md (Fig. 3,f), right Md with 2 free standing teeth and left with 6 standing teeth; Mx1 (Fig.3,g) distal endite with 9 setae; Mxp1 (Fig.4,c) exopod with 9 setae; Mxp2 (Fig.3,h) exopod with 7 setae, one more seta added to distal outer margin of basal segment of endopod and one additional seta on inner distal margin of penultimate segment; Mxp3 (Fig.3,i) endopod rudiment also tipped with 2 setae. Duration of this substage was 36-48 hours.

MYSIS I

MCL: 0.63 mm (0.60-0.66 mm); MTL: 2.04mm (1.97-2.14 mm).

Carapace with rostrum just falling short of anterior end of eye (Fig.5,a), rostrum withou

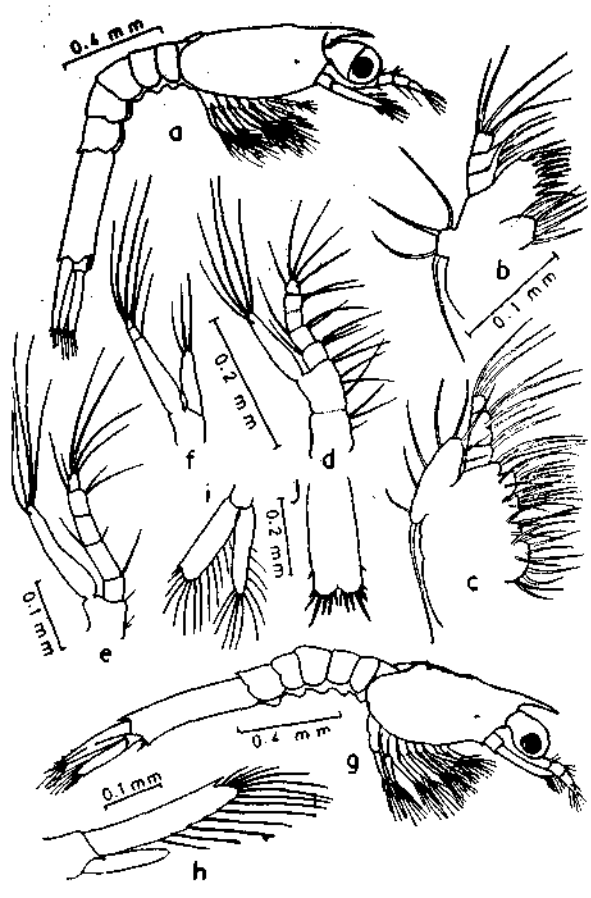

Fig. 5 *Metapenaeus dobsoni:* Mysis I: a - lateral view; b - Mx1; c - Mx2; d - Mxp2; e - Mxp3; f - P5. Mysis II: g - lateral view; h - A2; i - uropod; j - telson.

teeth, antennal and pterygostomial spines well developed, minute vestige of supraorbital spines may be present, minute hepatic spine present; abdominal segments 1 to 4 lack dorsal spines, 5th and 6th with dorsal spines, that on the 5th may be very small or rarely absent, no lateral spines on 5th and 6th segment, minute posteroventral pair of spines on 6th, a prominent ventromedian spine on posterior end of 6th segment at junction with telson; no pleopod buds on abdomen; telson (Fig.4,i) with 7+7 setae., deep cleft reaching level of origin of outermost pair of setae.

A1 (Fig.4,d) 3 segmented, basal segment with prominent ventral spine and slight basal swelling with 2 setae just above stylocerite rudiment, outer flagellum terminally with 1 seta and 6 aesthaetes, a bud-like inner flagellar rudiment bearing 2 setae, one long and one short, numerous setae at junction of segments; A2 (Fig.4,e) both exopod and endopod unsegmented, exopod scale-like with 10 setae and 1 short seta at distolateral angle, no spine on distal outer margin, endopod half length of exopod, bearing 3 terminal and 1 to 2 lateral setae; Md (Fig.4,f) asymmetrical, right with 3 and left with 6 free standing teeth, rudimentary palp present; Mx1 (Fig.5,b) distal endite with 10 setae; Mx2 (Fig.5,c) exopod with 9 setae, more setae added to endites; Mxp1 (Fig.4,g) number of setae on exopod reduced to 7, in rare instances all the 9 setae may be retained, below the proximal lateral seta, 1 to 2 small hair-like seta seen, 1 outer lateral seta added to penultimate and basal segments of endopod; Mxp2 (Fig.5,d), number of setae of exopod reduced to 6, in endopod 1 more inner seta added to 1st segment and 1 outer and 1 inner to 2nd segment, penultimate segment has become longer with indistinct segmentation in middle; Mxp3 (Fig.5,e) fully developed with 5 segmented endopod and unsegmented exopod, endopod with 5 terminal setae on distal segment, 2 inner and 1 outer on 4th segment, 1 outer and 1 inner on 2nd segment and 1 inner on basal segment, exopod with 4 terminal setae and a pair of subterminal setae; P1 to P3 almost identical (Fig.4,h) with unsegmented exopod bearing 4 terminal setae and 2 pairs of subterminal setae, endopod indistinctly divided into 2, distal larger segment with subterminal cleft representing incipient chela and tipped

with 3 long plumose setae; P4 and P5 (Fig.5,f) with unsegmented endopod tipped with 3 long setae, exopod with 4 terminal setae and 2 pairs of subterminal setae; uropod (Fig.4,i), exopod with 11 plumose and one non-plumose seta, endopod with 9 to 10 plumose setae. Duration of this substage was 24 to 36 hours.

MYSIS II

MCL: 0.64 mm (0.63-0.67 mm); MTL: 2.16 mm (2.08-2.31 mm).

Rostrum without teeth; carapace with no trace of supraorbital spines (Fig.5,g); no trace of pleopod buds yet; cleft of telson reaching only level of origin of penultimate pair of lateral setae (Fig.5,j).

A1 small otolith visible in basal swelling, 3 short setae just above stylocerite rudiment; A2 (Fig.5,h) scaphocerite with 13 setae and a distolateral spine, endopod without setae, protopod with ventral spine on distal segment; Md (Fig.6,b) right with 3 and left with 8 free standing teeth, palp larger; Mx1 (Fig.6,c) exopod lost; Mx2 (Fig 6,d) exopod with 10 setae, more setae added to endites; Mxp2 (Fig.6,e) endopod 5 segmented, one more seta added to distal segment and 1 outer lateral seta to 3rd segment; Mxp3 with an outer seta added to 3rd segment of endopod; P1 to P3 (Fig.6,f) with 1 long outer lateral seta added to endopod; P4 to P5 (Fig.6,g) show indistinct segmentation in endopod but no additional setae; uropod (Fig 5,i) exopod with 12 plumose setae and 1 short non-plumose seta at outer distal angle, at the base of this seta outer margin of exopod produced into a minute tooth which becomes a well defined fixed spine in later substages, endopod with 11 to 12 plumose setae, a short spine on ventral aspect of protopod. Duration of this substage was 24 to 36 hours.

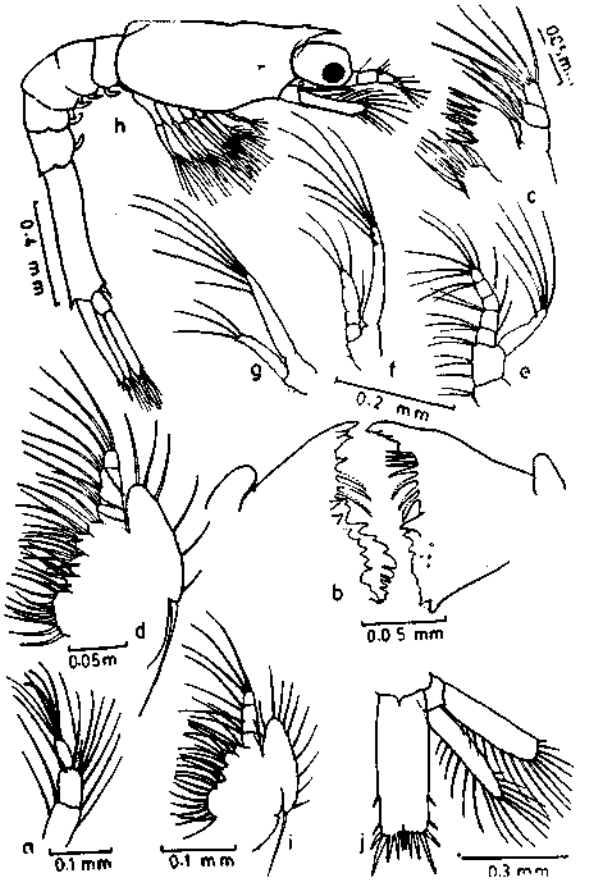

Fig. 6 *Metapenaeus dobsoni:* Mysis III: a - anterior part of A1; b - Md; c - Mx1; d - Mx2; e - Mxp2; f - P1; g - P4. Mysis III: h - lateral view; i - Mx2; j - uropod and telson.

MYSIS III

MCL: 0.71 mm (0.67-0.74 mm);MTL: 2.35mm (2.17-2.67mm).

1 rostral tooth present (Fig.6,h), no other change in the spination of carapace and abdomen; unsegmented pleopod buds developed; cleft in telson shallow (Fig.6,j).

Inner flagellum of A1 half size of outer; A2 (Fig.7,a) scaphocerite with 15 plumose setae and one anterolateral spine; Md palp larger; Mx2 (Fig. 6,i) exopod with 13 plumose setae; Mxp1 with one outer seta added to basal segment of endopod; Mxp2 with one short seta added to junction of exopod and endopod; P1 to P3 (Fig.7,b) endopod larger and 3 segmented, cleft of chela deep, one seta originating from cleft, a short inner seta added to basal segment; P4-P5 (Fig.7,c) endopod 3 segmented, distal segment may have 2 annulations indicating indistinct segments, basal segment acquires a long inner lateral seta and 2nd segment a long outer lateral seta; uropod (Fig. 6,j) exopod with 14 plumose setae and 1 non-plumose seta distolaterally, endopod with 14 to 15 setae. Duration of this substage was 36 to 48 hours.

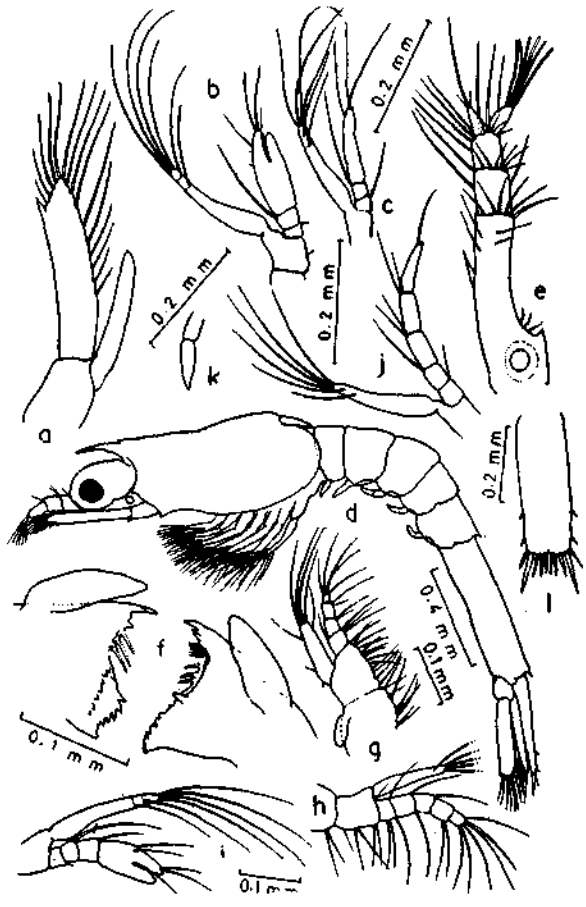

Fig. 7 *Metapenaeus dobosni:* Mysis III: a - A2; b - P1; c - P5. Mysis IV: d - lateral view; e - A1: f - Md: g - Mxp2: h - Mxp3; i - P1: j - P5: k - pleopod bud: l - telson.

MYSIS IV

MCL: 0.75 mm (0.74-0.77 mm); MTL: 2.56mm (2 52-2.62 mm).

2 rostral spines present (Fig.7,d); pleopods 2 segmented but small (Fig.7,k); cleft of telson very shallow (Fig.7,l); inner flagellum of A1 almost as long as outer (Fig.7,e); scaphocerite of A2 with 17 seate, endopod 2 segmented with 2 small lateral setae (Fig.8,a); palp of Md larger (Fig.7,f); distal endite of Mx1 with 11 setae; exopod of Mx2 with 15 setae; Mxp1 (Fig.7,g) with gill rudiment; P1 to P3 (Fig.7, i) with 4 segmented endopod, 1 outer seta added to 3rd segment, 2 outer seta added to base of dactylus; P4 to P5 (Fig.7,j) with 5 segmented endopod, dactylus pointed and tipped with 1 to 2 setae, a pair of outer setae added to carpus and propodus, endopods longer than exopods, exopod of uropod with 15 plumose setae and a non-plumose seta distolaterally, endopods with 15 plumose setae. Duration of this substage was 36 to 48 hours.

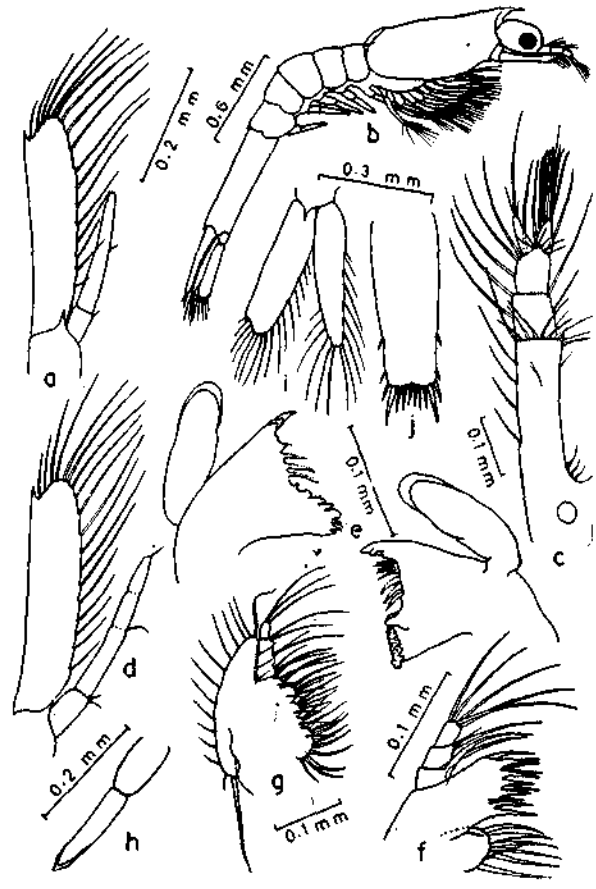

Fig. 8 *Metapenaeus dobsoni:* Mysis IV: a - A2. Mysis V: b - lateral view: c - A1: d - A2; e - Md: f - Mx1: g - Mx2: h - pleopod bud: j - telson.

MYSIS V

MCL: 0.80 mm (0.77-0.84 mm); MTL: 2.73 mm (2.48-2.97 mm).

Rostrum shorter, extending only to middle of eye (Fig.8,b); no other change in spination of carapace or abdomen; pleopods long and 2 segmented; telson almost truncate (Fig.8,j); A1 (Fig.8,c) with inner flagellum longer than outer; A2 (Fig.8,d) scaphocerite with 18 setae, endopod with 2 segments, the long distal segment bears 2 faint annulations and a short distal seta (Fig.8,d); Md (Fig.8,e) palps very large but without setae; Mx1 the slender seta on middle and basal segments of endopod may be absent (Fig.8,f); exopod of Mx2 with

17 setae (Fig.8,g); gill rudiments on protopod of Mxp1 (Fig.9,a) Mxp2 (Fig.9,b) and Mxp3 (Fig.9,c) present; P1 (Fig.9,d) endopods have

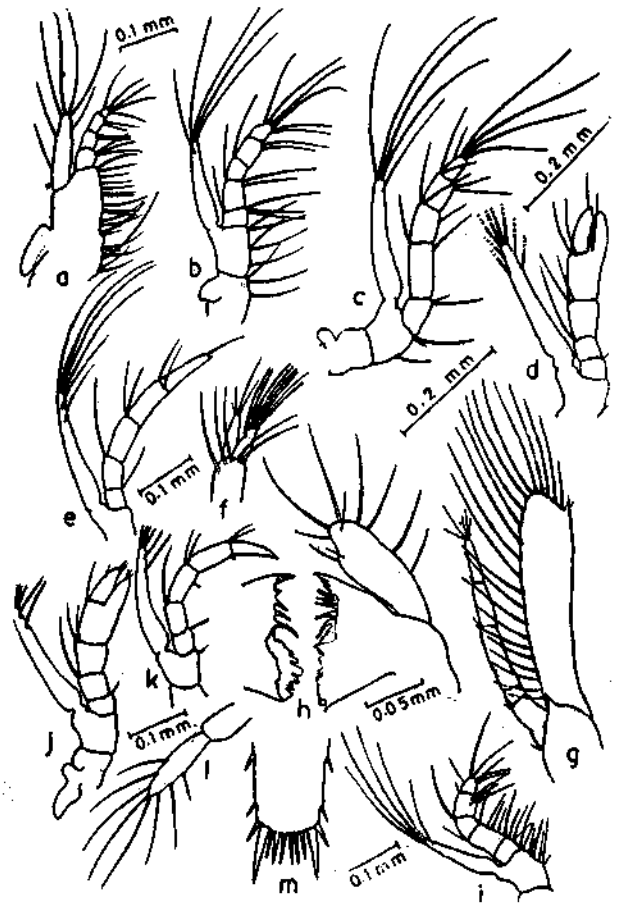

Fig. 9 *Metapenaeus dobsoni:* Mysis V: a - Mxp1: b - Mxp2; c - Mxp3: d - P1: e - P4. Intermediate stage I: f - A1 flagellum: g - A2: h - Md: i - Mxp2: j - P1: k - P5: l - fifth pleopod: m - tip of telson.

become longer, one more outer seta added to carpus of P1 to P3, dactylus clearly demarcated. Duration of this substage was 24 to 48 hours.

INTERMEDIATE STAGE I

MCL: 0.69 mm (0.68-0.70 mm); MTL: 2.88 mm (2.83-2.93 mm).

Rostrum very short extending to ¼ eye (Fig.10, m) pterygostomial spine absent; no dorsal spine on 5th abdominal segment; posterior margin of telson convex (Fig.9,m); pleopods fringed with 8 plumose setae (Fig.9,l) functional exopods of thoracic appendages retained.

A1, 5 setae above stylocerite, outer flagellum indistinctly 2 segmented (Fig.9,f); A2, scaphocerite with 22 to 23 setae; a very thin non-plumose seta present at outer base of anterolateral spine (Fig.9,g), endopod 5 segmented, distal segment tipped with 5 setae, 6 to 7 short setae on inner margin of endopod; Md palp unsegmented but with 9 to 10 setae, standing teeth retained (Fig.9,h); Mx1

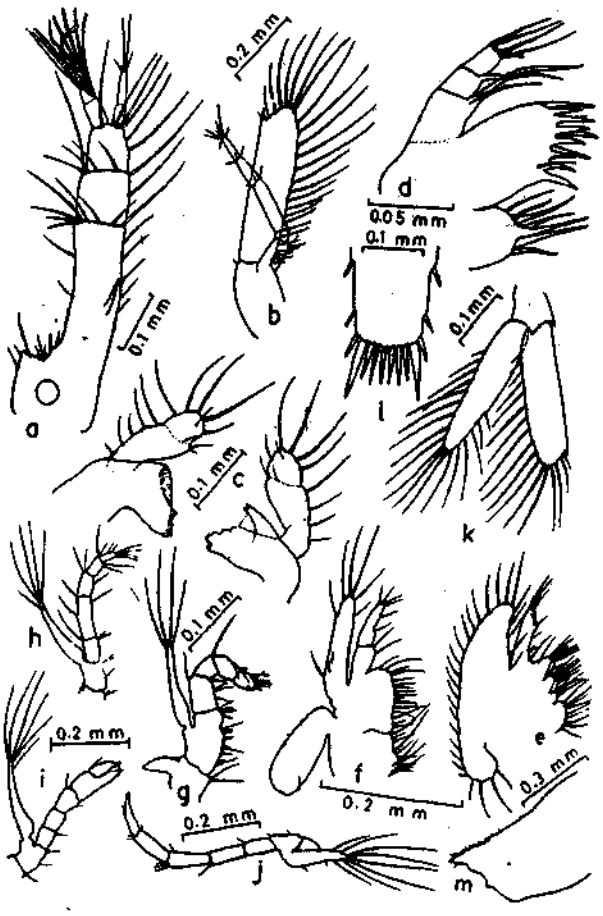

Fig. 10 *Metapenaeus dobsoni:* Intermediate stage II: a - A1; b - A2: c - Md: d - Mx1; e - Mx2; f - Mxp1; g - Mxp2; h - Mxp3; i - P1: j - P5: k - uropod: l - telson tip. m - rostrum and anterior part of intermediate stage I.

basal and middle segments of endopod have each lost 1 seta; Mx2 endopod segmentation lost, exopod with 22 setae; Mxp2 (Fig.9,i) endopod slightly sigmoid, more setae developed on inner margin of 1, 2 and 4 segments, P1 to P3 (Fig.9,j) with functional chelae, long outer setae retained, long terminal setae on dactylus lost; P4 and P5 (Fig.9,k) with sharply pointed dactylus which has lost the

long terminal seta, long outer setae retained; exopod of uropod with 17 plumose setae and a non-plumose seta, endopod with 16 setae; no setae on basal segment of pleopods (Fig.9,l). Duration of this substage was 24 to 36 hours.

INTERMEDIATE STAGE II

MCL: 0.76 mm (0.73-0 78 mm); MTL: 2.91 mm (2 88-2.95 mm).

Rostrum blunt with 2 dorsal spines; pleopods with 9 to 10 plumose setae; inner flagellum of A1 2 segmented (Fig.10,a); flagellum of A2 5 segmented tipped with 7 short setae, bristle-like setae at junction of segments (Fig.10,b); Md (Fig.10,c) standing teeth lost, palp faintly 2 segmented; Mx1 (Fig.10,d) terminal setae on endopod shortened; Mx2 (Fig.10,e) setae on endopod reduced in size, distal endite of protopod vestigial, exopod with 27 to 28 setae; Mxp1 (Fig.10,f) endopod setae highly reduced, protopod broader, exopod still with long setae, gill rudiment long; Mxp2 (Fig.10,g) endopod recurved, long plumose setae along inner margin replaced by stout setae, exopod still with long plumose setae; Mxp3 (Fig.10,h), setae on endopod reduced in length, exopod still with long plumose setae; P1 to P5 (Fig.10,i and j) have lost the long outer setae on endopod, exopods still with long setae; telson with convex posterior margin (Fig.10,l); uropod (Fig.10,k), no change in exopod, endopod with 18 setae; pleopods, distal segment longer with 10 plumose setae, basal segment broader with 2 distolateral short setae. Duration of this substage was 24 to 36 hours.

POSTLARVA I

MCL: 0.73 mm (0.73-0.78 mm); MTL: 2.65 mm (2,60-2.72 mm).

Rostrum blunt with 2-3 dorsal spines (Fig. 11,a); dorsal spine on 5th abdominal segment and posteromedian ventral spine on 6th abdominal segment lost; A1 (Fig.11,b) both inner and outer flagella 2 segmented; A2 (Fig.11,c), no appreciable change; Md (Fig. 11,d) palp clearly 2 segmented, standing teeth replaced by thin blade like cutting edge; Mx1 (Fig.11,e), endopod segmentation lost and setae hightly reduced in size, 12 setae on distal endite; Mx2 (Fig.11,f), endopod further reduced; Mxp1 (Fig.11,g) endopod segmentation lost, setae highly reduced, exopod setae also reduced in size, protopod broader; Mxp2 (Fig.11,h) exopod without setae and reduced in size, endopod sharply recurved; Mxp3 (Fig.11,i), exopod reduced in size, setae lost; P (Fig.12,a to e), exopod of all legs shrunken, without setae; pleopods (Fig.12,f,g), distal

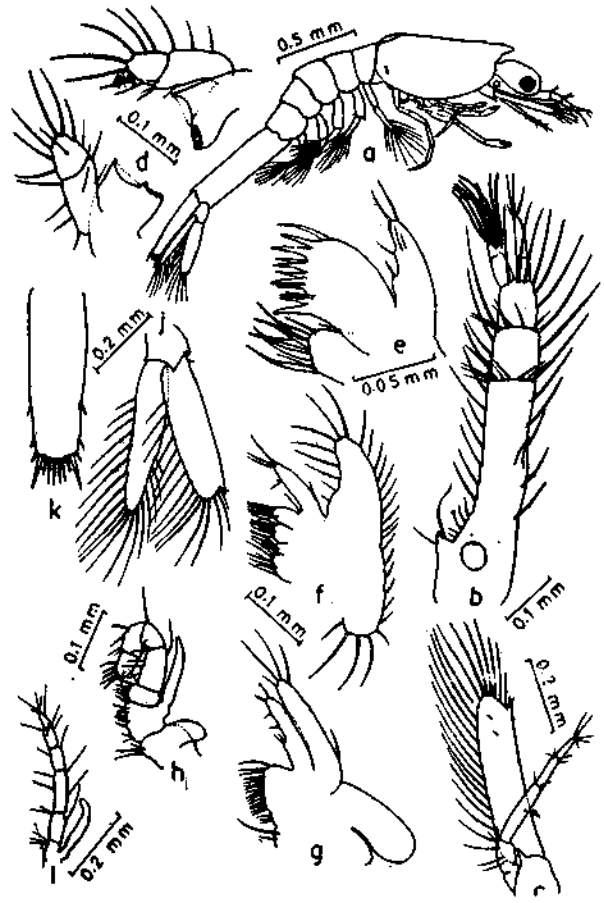

Fig. 11 *Metapenaeus dobsoni*: Postlarva I: a - lateral view; b - A1; c - A2; d - Md; e - Mx1; f - Mx2; g - Mxp1; h - Mxp2; i Mxp3; j - uropod; k - telson.

segment long and narrow with 10 plumose setae, basal segment broader with lateral setae in middle of segment also; uropod (Fig.11,j), endopod with 19 setae, no change in exopod, telson with convex posterior end (Fig.11,k).

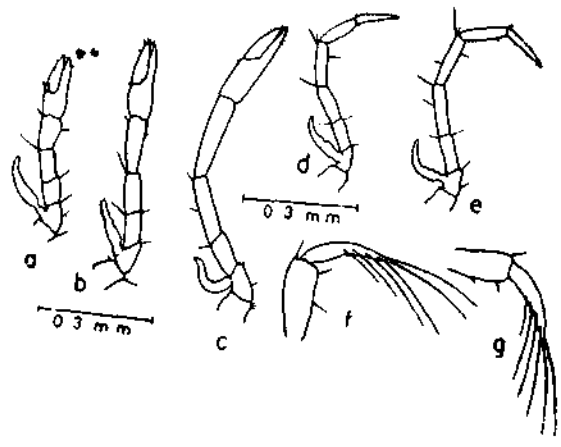

Fig. 12 *Metapenaeus dobsoni:* Postlarva 1: a - P1; b - P2; c - P3; d - P4; e - P5; f - third pleopod; g - fourth pleopod.

DISCUSSION

The eggs of *M. dobsoni* are large and have a characteristically wide perivitelline space which is perhaps responsible for making the eggs of this species more buoyant than those of the other species of penaeids. The slightest agitation of the water stirs them up from the bottom and keeps them suspended in water. This may be the reason for getting the eggs of *M. dobsoni* very frequently in the surface plankton hauls, from the inshore region. The eggs described by Subrahmanyam (1965, *J. mar. biol. Ass. India.* 7(1): 83-88[5]) from the inshore plankton of Madras as those belonging to *P. indicus* were most probably the eggs of *M. dobsoni* as they were large (0.45-0.47 mm) with a wide perivitelline space.

6 nauplius substages were observed during the present study. Menon[1] recorded only 3 nauplius substages while Rao[3] described 2 more substages and Thomas *et. al.*[4] have reported 6 nauplius substages. These earlier descriptions of the nauplius substages can be equated with the present description as follows:-

Present work	NI	NII	NIII	NIV	NV	NVI
Menon[1]	NI		...	...	NII	NIII
Rao[3]	NI		..	NII	NIII & NIV	NV
Thomas *et. al.*[4]	NI	NII	...	NIII	NIV & NV	NVI

The N I of Menon[1] appears to combine the characters of N I and N II. The 2 long terminal setae and the long outer lateral seta of the A1 shown in his Fig.4 resemble those of N I, but in the same figure the A2 and Md are shown with plumose setae. The plumose setae are acquired only in N II, the setae are not plumose in N I. Further in Fig. 4 of Menon[1] there are only 2 inner lateral setae on A1. During the present observation 3 inner lateral setae are clearly seen even in N I. The N II of Menon[1] with 6 pairs of furcal spines is clearly equivalent to our N V; but the relative length of the terminal setae on A1 is different. N III of Menon[1] is similar to our N VI except for the very prominent A1 segmentation.

N II of Rao[3] agrees with our N IV in the number of furcal spines and in the setation of the A2 endopod but the setation of the A1 and A2 exopod are slightly different. N III and N IV of Rao[3] appears to be equivalent to our N V; the 6th pair of minute furcal spines are not easily visible in preserved material. This is confirmed by the statement of Rao[3] that in N IV which is said to bear 6 pairs of furcal spines the "setation of the appendages remains same as in the previous substage". Progressive addition of setae in each substage was noticed during the present investigations. N III and N IV of Rao[3] also appear to have more number of setae on A2 exopod, than our N V. NIII with 3 pairs of furcal setae appears to have been overlooked by the earlier workers; the minute pair of inner spines is very small indeed and is not seen well in dorsal view.

The spination of the carapace and abdomen of 3 protozoea substages described by Menon[1] is similar to our observations, but many setae have been missed by him in his illustrations of the appendages; especially those of the A2, Mx2, Mxp1 and Mxp3. The setal formula of 1+2+3 lateral setae on the A2 endopod appears to be characteristic; out of the 3 distal lateral setae, 2 are long and 1 is short, hair-like and could easily be overlooked. Menon[1] has shown only 2+2 lateral setae and 4 terminal setae instead of 5. He has also shown lesser number of setae on the exopod of Mxp1 and Mxp2.

All previous workers reported only 3 mysis substages for *M. dobsoni*. During the present investigations 5 substages were observed. The transition from one substage to the next is very gradual but clearly marked by increase in (a) length of the pleopods, (b) the size of the larvae and (c) in the number of setae on the scaphocerite and exopod of Mx2.

Menon[1] and Rao[3] have stated that mysis I of *M. dobsoni* has no hepatic spines. But during the present study a minute hepatic spine was observed in mysis I. Rao[3] stated that the dorsal spine on the 5th abdominal segment is absent in mysis stages of *M. dobsoni* and used this character to distinguish the mysis of *M. dobsoni* in the key provided by him. But after examining hundreds of specimens during the present study we found that the dorsal spine on the 5th abdominal segment is normally present in the mysis substages of *M. dobsoni* although it is distinctly smaller than in *M. affinis* and *M. monoceros*. Only very rarely was it found to be absent,. The size of this spine is highly variable and sometimes it is represented by a minute tooth; when compared with the present observations, the Mx1, Mx2, Mxp1, Mxp2, and Mxp3 of mysis I described by Rao[3] appear to be deficient in the number of setae.

As a deviation from the normal course of development the last mysis substage sometimes moults into one of the intermediate substages described in the present paper before transforming into postlarva I.

VI

Larval development — *METAPENAEUS AFFINIS* (H. MILNE EDWARDS)

M. S. Muthu
N. N. Pillai
K. V. George

The complete larval development of *Metapenaeus affinis* was studied by rearing them in the laboratory at Narakkal. At the rearing temperature of 25.2° C-27.0° C the embryo takes 15 to 17 hours to hatch out; the nauplius transforms into protozoea I 42 to 56 hours after it hatches out of the egg, the protozoea stage lasts for 4 to 8 days and the mysis I takes 6 to 9 days to transform into postlarva I. Complete larval development from egg stage to postlarva I takes 14 to 23 days. 6 nauplius substages, 3 protozoea substages, 5 mysis substages and 2 intermediate stages were observed during the course of development. All the larval substages are described and illustrated and compared with the earlier descriptions of this species.

The penaeid prawn *Metapenaeus affinis* which is of commercial importance on the west coast of India, spawned in the laboratory at Narakkal on a number of occasions and the larvae were reared to the juvenile stage successfully. While checking the morphological features of the larvae with the earlier larval descriptions of *M. affinis* given by Mohamed *et al.*, (1968) *FAO Fish. Rep.*, 57 (2): 487-503[1]), Rao (1974, *J. mar. biol. Ass. India*, 15 (1): 95-124)[2], and Thomas *et.al.* (1976, *Indian J.Fish.*, 21 (2): 543-556)[3], marked differences in the setation of the appendages and in the number of mysis substage were noticed. Hence the larval characters of *M. affinis* observed during the present study are fully described and illustrated in this paper to bring out the exact nature of setation of the larval appendages. The temperature of the water in the rearing basins was 25.2° C-27.0° C and the salinity 33.2-34.6 ppt.

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DESCRIPTION OF DEVELOPMENTAL STAGES

EGG

Opaque, diameter of egg varied from 0.25 to 0.27 mm and that of yolk mass from 0.21 to 0.24 mm (Fig.1,a]; eggs hatch out 15 to 17 hrs after spawning.

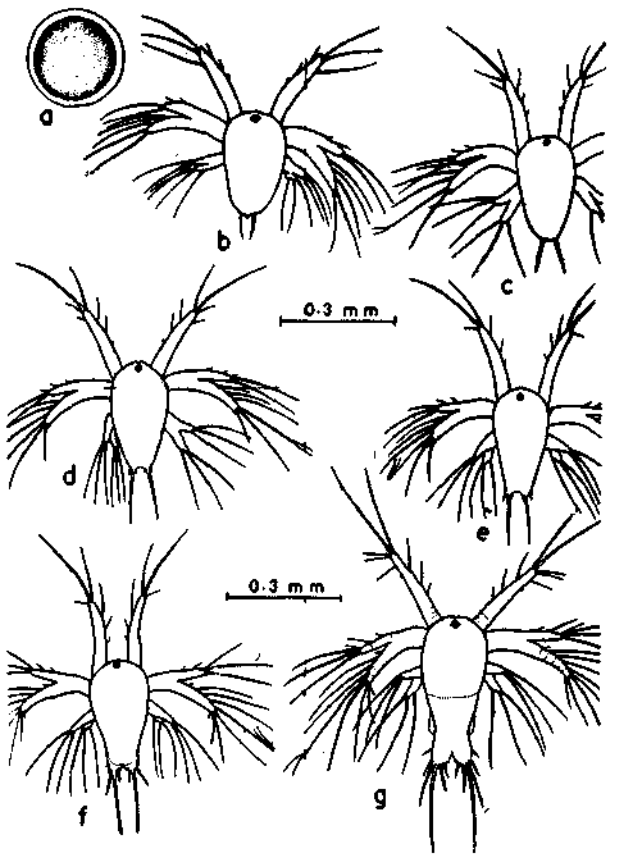

Fig. 1 *Metapenaeus affinis:* a - egg; b - Nauplius I; c - Nauplius II; d - Nauplius III; e - Nauplius IV; f - Nauplius V; g - Nauplius VI.

NAUPLIUS I

MTL: 0.25 mm (0.24-0.27 mm;) MW: 0.15mm; MFS:0.06 mm (0.05-0.08 mm).

An ocellus present in anterior end; it persists in all nauplius substages; A1 uniramous carrying distally 1 rudimentary spike-like seta and 2 long setae, 1 seta as long as the long terminal setae present at outer distal margin, inner margin with 3 short setae (Fig. 1,b); A2 biramous, endopod with 2 short inner lateral setae and one rudimentary and 2 long apical setae, exopod with 5 long setae along inner and distal margin; Md biramous, exopod and endopod carrying 3 long setae distally; setae nonplumose; furcal setae 1+1; a small median dorsal spine present posteriorly. Duration of this substage was 3-4 hours.

NAUPLIUS II

MTL: 0.26 mm (0.25-0.27 mm); MW: 0.07 mm (0.07-0.08 mm); MFS: 0.15 mm (0.14-0.15 mm).

Setae plumose; furcal setae 1+1 (Fig.1,c); A1 with 3 short setae on the inner margin, distally with 3 setae, 1 short seta present at outer distal margin; A2 exopod with 5 long setae along inner and distal margin, and distally a rudimentary seta, 4th seta from proximal end distally split, this bifurcated condition of the seta is retained in all subsequent nauplius substages. Duration of this substage was 3-4 hours.

NAUPLIUS III

MTL: 0.26 mm (0.25-0.27 mm); MW: 0.15 mm (0.14-0.15 mm); MFS: 0.11 mm (0.09-0.11 mm).

Furcal setae 3+3 (Fig.1d); exopod of A2 with 6 long plumose setae and 1 rudimentary seta Duration of this substage was 6-8 hours.

NAUPLIUS IV

MTL: 0.27 mm (0.26-0.28 mm); MW: 0.15mm (0.14-0.15 mm); MFS: 0.13 mm (0.13-0.14 mm).

Furcal setae 4+4 (Fig.1,e);. A1 outer distal seta present in earlier stages lost; endopod of A2 distally carries 3 long plumose setae and 2 short setae on inner margin. Duration of this substage was 4-6 hours.

NAUPLUS V

MTL: 0.27 mm (0.26-0.28 mm); MW: 0.15 mm (0.14-0.15 mm); MFS: 0.17 mm (0.16-0.18 mm).

Furcal setae 6+6 (Fig. 1, f); developing frontal organ seen; exopod of A2 with 7 long and 2 short setae; a swelling at the base

of Md present. Duration of this substage was 10-12 hours.

NAUPLIUS VI

MTL: 0.35 mm (0.34-0.36 mm); MW: 0.16 mm); (0.15-0.17 mm); MFS: 0.22 mm (0.21-0. 22mm).

Body slightly elongated, developing carapace seen, furcal setae 7+7 (Fig. 1, g); 3 more setae, 2 medium and 1 short, added to outer distal margin of A1, indistinct segmentation seen in proximal part; endopod of A2 with 2 short setae on inner margin and 1 short and 3 long plumose setae distally; exopod with 9 setae along inner and distal margin, proximal inner seta small; cutting edge of developing Md visible inside basal swelling of Md. Duration of this substage was 16-24 hours.

PROTOZOEA I

MTL: 0.77 mm (0.77-0.78 mm); MCL: 0.37 mm (0.35- 0.38 mm).

Carapace rounded anteriorly with a median notch, frotnal organs overhurg by fronral horns (Fig. 2, a), ocellus persists; each furcal lobe with 7 setae.

A1, 3 segmented, proximal segment divided into 5 subsegments, 1st and 2nd segments carry 1 and 2 setae respectively on inner margin, distal segment carries 3 aesthaetes and 2 setae of which 1 seta more than twice length of the other; exopod of A2 (Fig. 2, a) 10 segmented carrying 10 long plumose setae along inner and distal margin and 2 setae on outer margin, endopod 2 segmented, distal segment apically with 5 long plumose setae, basal segment with 1+2+3 inner lateral setae; Md (Fig.2,b) devoid of exopod and endopod, almost symmetrical with 1 free standing tooth in between incisor and molar processes; Mx1 (Fig.2,c) protopod unsegmented with 2 large lobes, distal lobe with 4 setae and proximal with 7 setae, exopod knob-like and bears 4 long feathery setae, endopod 3 segmented, distal segment carries apically 5 long setae, middle segment carries 2 stout setae and proximal segment with 1 slender and 2 stout setae; Mx2 (Fig.2 d) protopod with 5 endites on inner side, basal endite bearing 6 to 8 setae and other endites with 3 to 4 setae, exopod carries 5 long feathery setae, endopod with 3 distinct segments, the large middle segment partially divided into 2 by indistinct segmentation, 1 to 3 segments carrying 2 setae each on inner side and distal

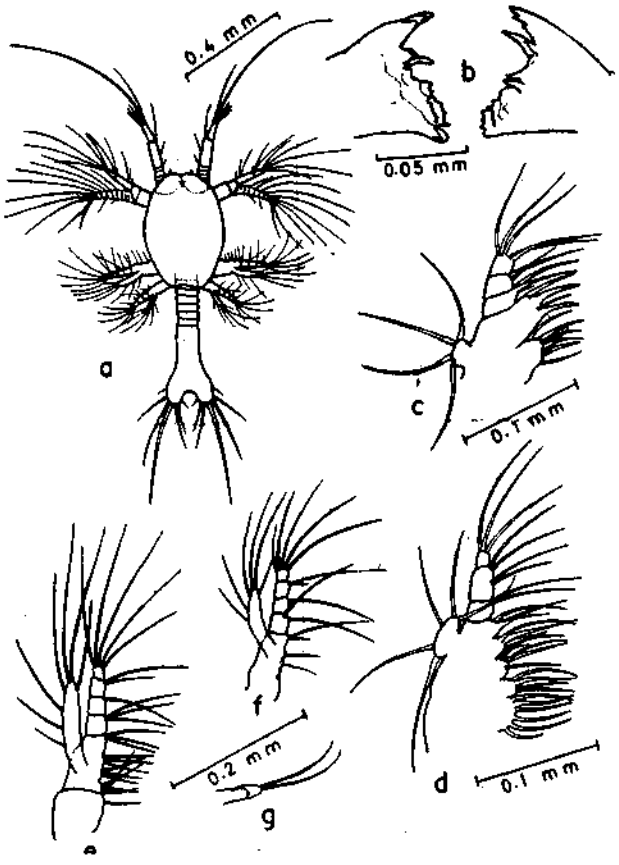

Fig. 2 *Metapenaeus affinis:* Protozoea I: a - dorsal view; b - Md; c - Mx1; d - Mx2; e - Mxp1; f - Mxp2; g - Mxp3.

one with 3 long setae; Mxp1 (Fig.2,e) protopod 2 segmented, proximal with 3 to 4 and distal with 11-12 setae on inner side, exopod shorter than endopod carrying 7 long plumose setae, endopod 4 segmented, distal segment with 5 long plumose setae, 1st, 2nd and 3rd segments carrying on inner side 3,1 and 2 setae respectively; Mxp2 (Fig.2,f) protopod indistinctly segmented, exopod with 6 long plumose setae, endopod 4 segmented, distal segment carries 5 long plumose setae, 1st, 2nd and 3rd segments with 2, 1 and 2 setae respectively; Mxp3 (Fig. 2,g) biramous, exopod with 2 long setae apically. Duration of this substage was 24-72 hours.

PROTOZOEA II

MTL: 1.23 mm (1.19-1.26 mm): MCL: 0.50 mm (0.49-0.53 mm).

Stalked eyes developed, rostrum prominent, rostral platform with blunt anterolateral corners, supraorbital spines present (Fig.3,a); 7 setae on each furcal lobe.

A1 (Fig. 3,b) distal segment with 3 aesthaetes, 3 setae and a spike-like rudimentary seta; Md (Fig. 3,d) asymmetrical, left wtih 5 free standing teeth and right Md with one standing tooth; Mx1, distal endite of protopod with 7 setae; Mx2, number of setae on endite of protopod increased, a small setae added to 3rd segment of endopod of Mxp1; exopod rudiment of Mxp3 with 3 setae (Fig. 3,e). Duration of this substage was 24-48 hours.

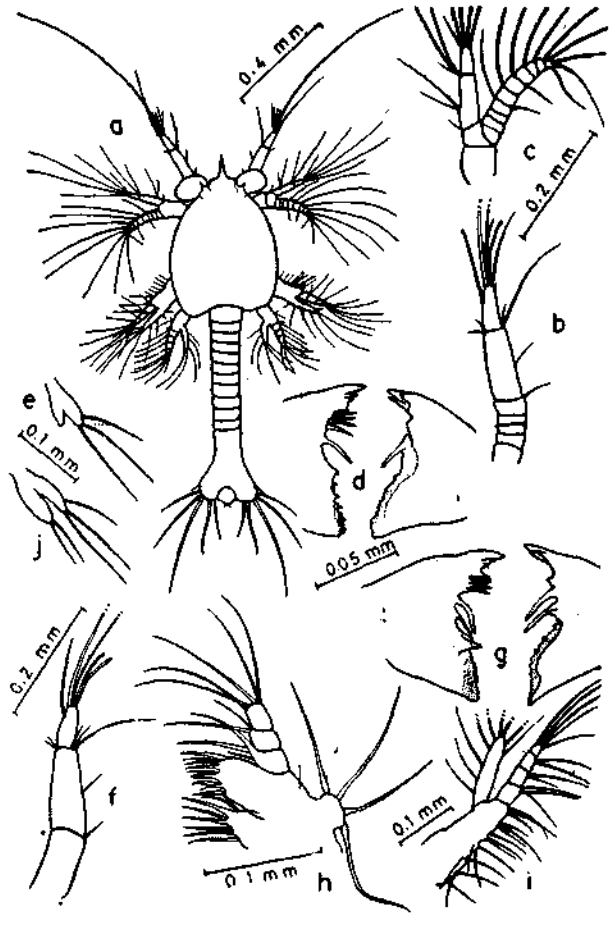

Fig. 3 *Metapenaeus affinis:* Protozoea II: a - dorsal view; b - A1; c - A2; d - Md; e - Mxp3; Protozoea III: f - A1; g - Md; h - Mx1; i - Mxp1; j - Mxp3.

PROTOZOEA III

MTL: 1.85 mm (1.77-2.03mm); MCL: 0.63mm.

Rostrum prominent; abdominal segments 1 to 5 with postero-dorsal spines (Fig.4,a,) 5th segment carries posterolateral spines, 6th segment with a pair of ventrolateral spines, 7 setae on each furcal lobe, uropod biramous.

A1 (Fig. 3,f) 3 segmented; subdivisions of the basal segment vanished; Md(Fig.3,g) left and right Md with 6 and 2 free standing teeth respectively; Mx1(Fig.3,h) distal endite of protopod with 9 and proximal with 7 setae; exopod of Mxp1 with 9 plumose setae (Fig.3,i); exopod and endopod of Mxp3 (Fig.3,j) with 3 and 2 setae respectively; exopod of uropod with 6 short setae, endopod bare. Duration of this substage was 48 to 72 hours.

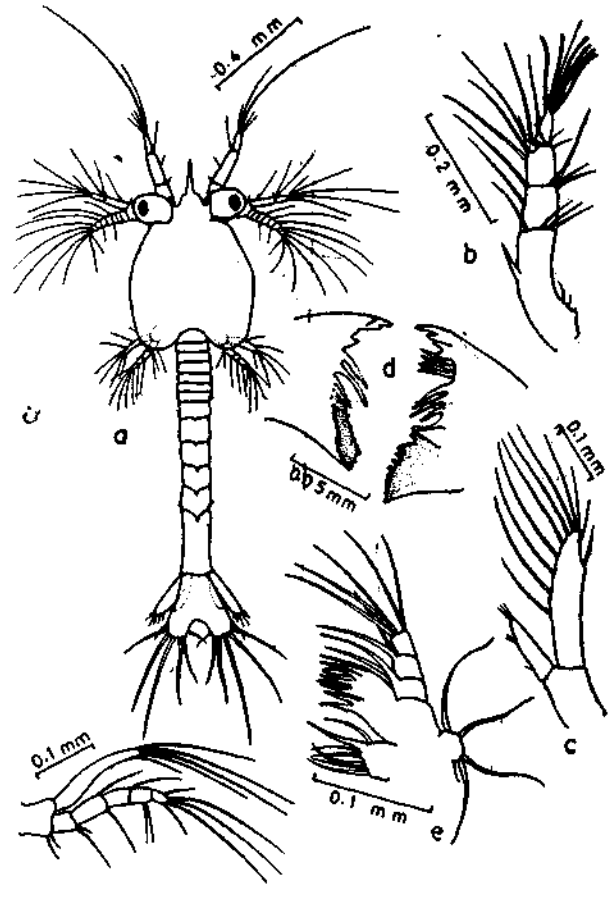

Fig. 4 *Metapenaeus affinis:* Protozoea III: a - dorsal view. Mysis I: b - A1; c - A2; d - Md; e - Mx1; f - Mxp3.

MYSIS I

MTL: 2.27 mm (2.21-2.38 mm); MCL: 0.77 mm (0.77-0.79 mm):

Rostrum devoid of teeth, extends beyond eye; antennal and pterygostomial spines present (Fig.5,a); dorsal median spine present on 5th and 6th abdominal segments; telson with a median deep cleft and carries 7+7 setae (Fig.5,e).

A1 (Fig.4,b) 3 segmented, just above stylocerite rudiment a slight swelling carrying 2 short plumose setae present, basal segment with prominent ventral spine, distal segment carries 2 flagellar rudiments, outer flagellum with 6 aesthaetes and 1 seta, inner flagellum small, bud-like bearing apically 2 setae, one long, slender and the other short; A2 (Fig.4,c) exopod unsegmented, scale-like bearing 10 setae along inner and distal margin and a seta at disto-lateral angle; endopod ½ length of exopod bearing 3 short terminal and 3 small inner lateral setae; Md (Fig.4,d) left and right Md with 7 and 3 free standing teeth respectively; Mx1 (Fig.4,e) distal endite with 10 setae and proximal endite with 7 setae; exopod of Mx2 with 9 plumose setae; Mxp1 (Fig.5,b) exopod with 7 plumose setae, 1 seta added to 1st segment of endopod at outer margin. Mxp2 (Fig.5,c) exopod carries 6 setae, endopod 4 segmented distal segment carries 5 setae, 1st, 2nd and 3rd segments each with 2 setae on inner side, 1st and 2nd segments carry 1 seta on outer side; Mxp3(Fig.4,f) fully developed, exopod unsegmented with 4 long apical and 2 subapical plumose setae, endopod 5 segmented, distal segment with 5 long setae apically, 1st, 2nd and 4th segments carry 2, 1 and 2 setae on inner margin, 2nd and 3rd segments carry 1 seta on outer distal margin; P1 to P5 almost identical (Fig.5,d), exopod unsegmented bearing 4 apical and 4 subapical long plumose setae, endopod partially divided into 2, distal segment bearing 3 long setae; uropod (Fig.5, e) well developed, exopod with 12 plumose setae and 1 short nonplumose seta distolaterally, endopod with 10 setae. Duration of this substage was 24-36 hours.

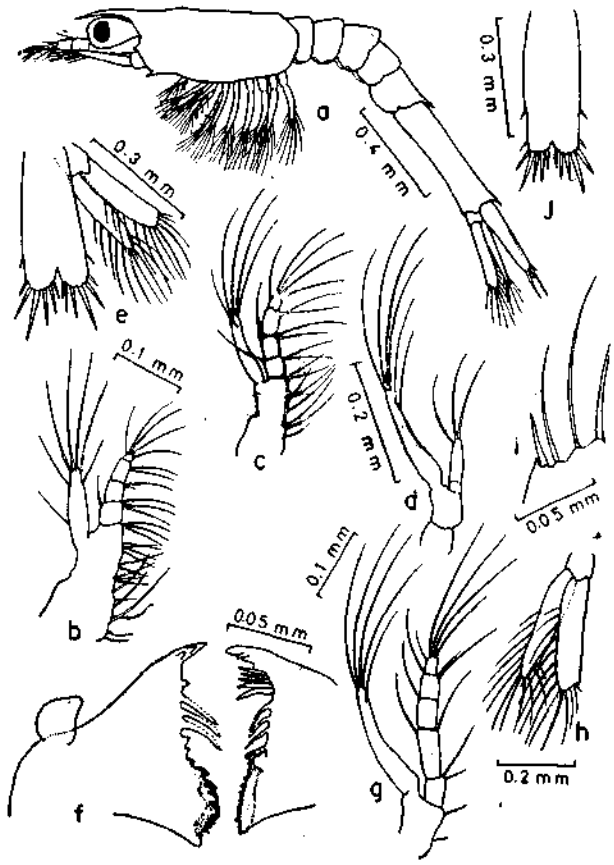

Fig. 5 *Metapenaeus affinis*: Mysis I: a - lateral view; b - Mxp1; c - Mxp2; d - P1; e - uropod and telson. Mysis II: f - Md; g - Mxp3; h - uropod; i - distolateral tip of exopod of uropod; j - telson.

MYSIS II

MTL: 2.42 mm (2.28-2.6 mm ; MCL: 0.79 mm (0.77-0.81 mm).

Rostrum with 1 dorsal tooth, small hepatic spine present (Fig.6,a); pleopod buds not yet developed; cleft of telson reaching only level of origin of penultimate pair of lateral setae (Fig.5,j).

A1 (Fig.6,b) with 3 short plumose setae just above stylocerite rudiment, a small otolith visible in basal segment; A2 (Fig 6,c) endopod unsegmented without setae and exopod with 15 setae and 1 distolateral spine; Md (Fig.5,f) rudimentary palp developed, right and left Md with 3 and 8 free standing teeth respectively; Mx1 (Fig.6,d) exopod completely lost; Mx2 (Fig.6,e) exopod with 11 setae, number of setae increased in endities of protopod; Mxp2 endopod 5 segmented, 1st, 2nd and 3rd segments carry on outer margin 1 seta each, distal segment with 6 setae; Mxp3 (Fig.5,g) 2nd. 3rd and 4th segment of endopod with

1 seta on outer distal margin; P1 to P3 identical (Fig.6,f) endopod indistinctly 3 segmented, basal 2nd segment with 1 seta on outer side, cleft of chela started developing, distal segment with 3 long setae; P4 and P5 (Fig.6,g) identical, endopod indistinctly divided into 3 segments bearing 3 long setae distally and 1 long seta on the outer margin; exopod

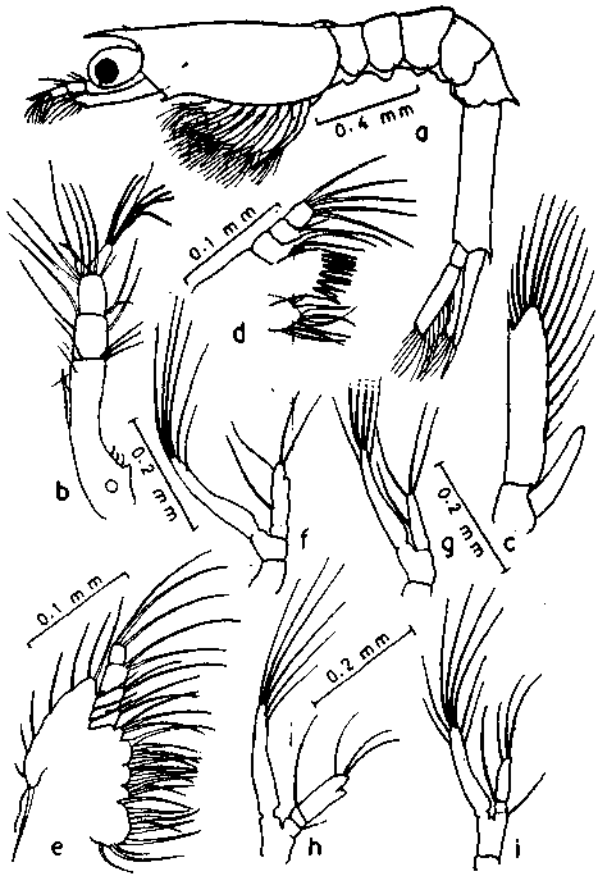

Fig. 6 *Metapenaeus affinis* Mysis II: a - lateral view; b - A1; c - A2; d - Mx1; e - Mx2; f - P1; g - P4; Mysis III: h - P2; i - P4.

of uropod (Fig.5,h) with 13 to 14 plumose setae and 1 short nonplumose seta on outer distal angle, at base of this seta outer margin of exopod produced into a minute tooth which becomes a well defined fixed spine in later substages (Fig.5,i), endopod with 12 to 13 setae; Duration of this substage was 24 to 36 hours.

MYSIS III

MTL: 2.81 mm (2.56-3.12mm); MCL: 0.87 mm (0.84 - 0.88 mm).

Rostrum with 1 drosal spine, pleopod buds small and unsegmented (Fig.7,a); cleft of telson hardly extending to level of origin of penultimate lateral seta.

A1 (Fig. 7,b) inner flagellum half length of outer, bearing 2 terminal setae, utoer with 7 aesthaetes and 1 seta; A2 (Fig.7,c) endopod unsegmented, more than half length of

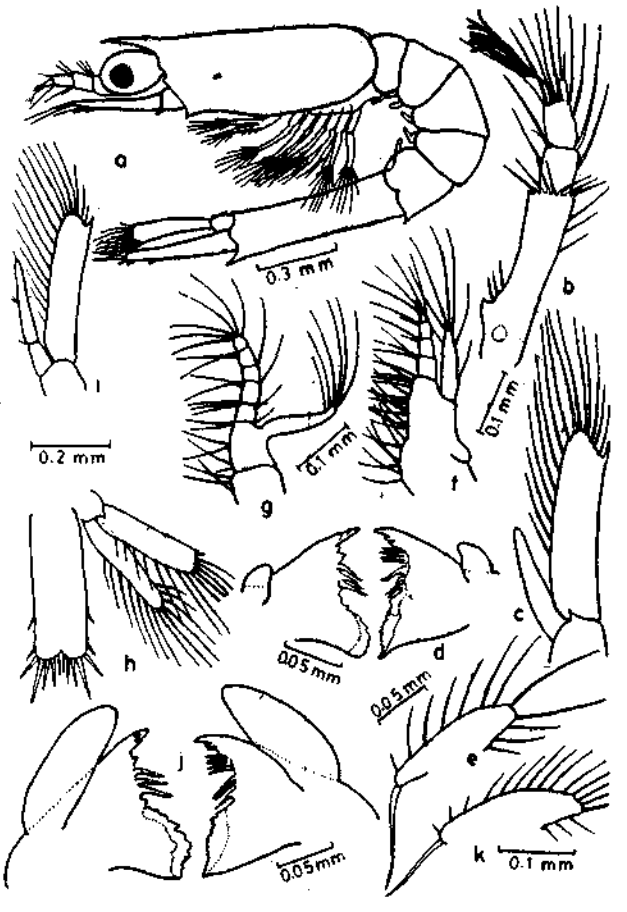

Fig. 7 *Metapenaeus affinis;* Mysis III: a - lateral view; b - A1; c - A2; d - Md; e - exopod of Mx2; f - Mxp1; g - Mxp2; h - uropod and telson. Mysis IV: i - A2; j - Md; k - exopod of Mx2.

exopod, exopod with 15 plumose setae and 1 distolateral spine; Md palp further developed (Fig.7,d); Mx2 (Fig.7,e) exopod with 13 to 14 plumose setae; Mxp1 gill rudiment present (Fig.7,f); Mxp2 with outer lateral seta on 1 to 3 segments of endopod (Fig.7,g); P1 to P3 (Fig.6,h) endopod 3 segmented, 1st segment with one inner seta, 2nd with 1 outer seta, 3rd with 3 terminal setae; P4 and P5 (Fig.6,i) with 2 segmented endopod, 1st segment with one long outer seta and

the distal with 3 setae, cleft of telson much reduced (Fig. 7,h); exopod of uropod with 13 to 14 plumose setae, one nonplumose seta and a minute distolateral spine; endopod with 13 plumose setae. Duration of this substage was 36 to 48 hours.

MYSIS IV

MTL: 2.9 mm (2.89-3.30 mm); MCL: 0 89 mm (0.84-0.92 mm).

Rostrum with 2 dorsal spines (Fig.8,a) pleopod 2 segmented (Fig.8,h), no cleft in telson, posterior part truncate (Fig.8,i).

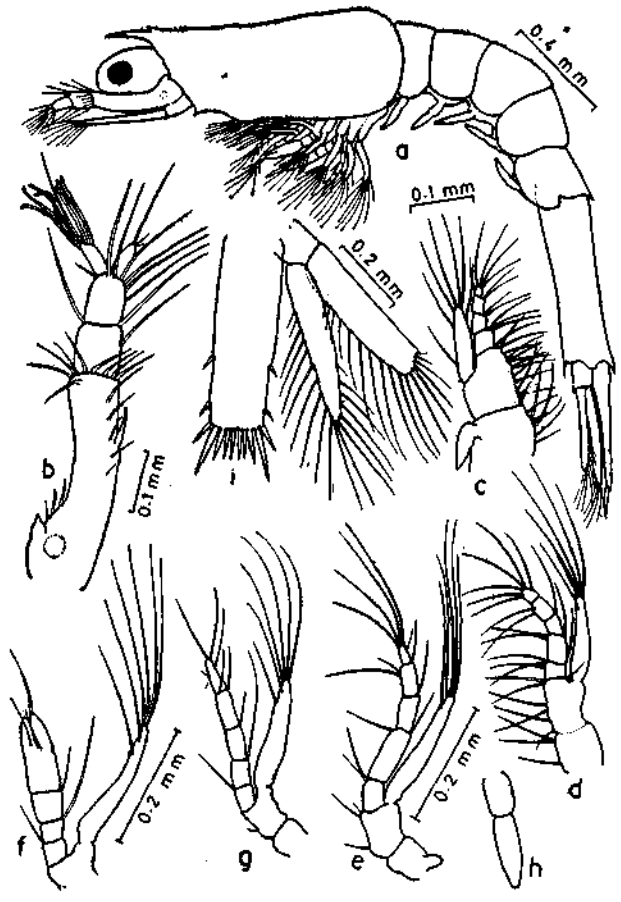

Fig. 8 *Metapenaeus affinis:* Mysis IV: a - lateral view; b - A1; - c Mxp1; d - Mxp2; e - Mxp3. f - P1: g - P4' h - pleopod II: i - uropod and telson.

A1 inner flagellum as long as outer with 7 aesthaetes and 1 seta (Fig.8,b); A2 exopod with 17 to 18 plumose setae and 1 distolateral spine, endopod 2 segmented, more than half length of exopod (Fig.7,i); Md (Fig.7,j) with prominent but unsegmented palp devoid of setae; Mx2 exopod with 18 plumose setae (Fig.7,k); Mxp1 (Fig.8,c) with gill rudiment on protopod further developed; no appreciable change in Mxp2 (Fig 8,d) and Mxp3 (Fig.8,e) P1 to P3 (Fig.8,f) endopod 4 segmented, 2nd and 3rd segments with 1 seta on outer side; P4 and P5 (Fig.8;g) endopod 5 segmented, 1st 3 segments with 1 seta, 4th segment with 2 setae and 5th with 3 to 4 setae, exopod with 4 apical and 2 pairs of subapical plumose setae; exopod of uropod (Fig.8,i) with 15 to 16 plumose setae, 1 nonplumose seta and a distolateral spine, endopod with 16 to 18 plumose setae. Duration of this substage was 36 to 48 hours..

MYSIS V

MTL: 3.20 mm (3.05-3.44 mm); MCL: 0.94 mm (0.91-0.95 mm).

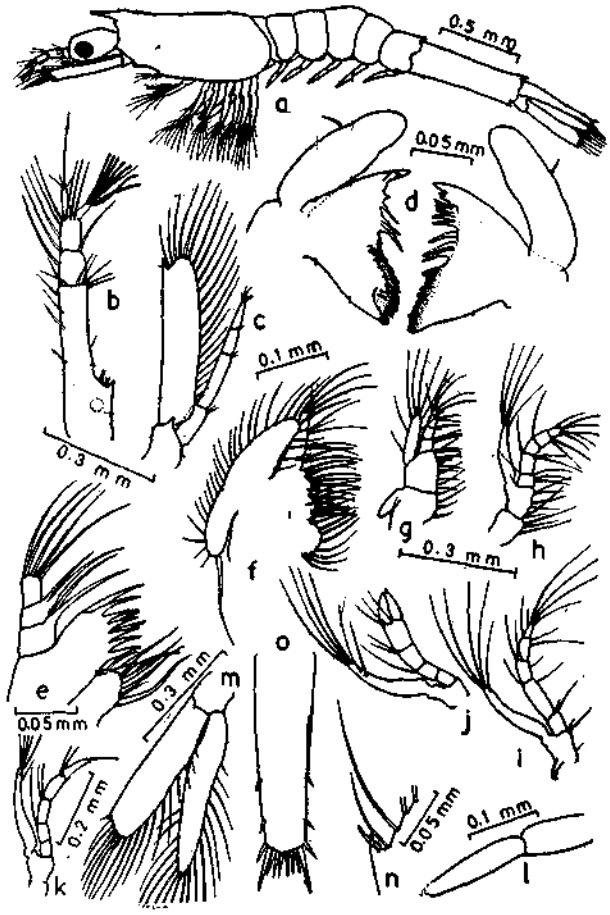

Fig. 9 *Metapenaeus affinis;* Mysis V: a - lateral view: b - A1: c - A2: d - Md: e - Mx1: f - Mx2: g - Mxp1: h - Mxp2: i - Mxp3; j - P1: k - P4; l - pleopod; m - uropod; n - distolateral margin of exopod of uropod; o - telson.

Rostrum greatly reduced in length, hardly reaching half eye (Fig.9,a); pleopods terminally with 4 short setal rudiments (Fig.9,l); telson posteriorly convex (Fig.9,o).

A1 (Fig.9,b) inner flagellum longer than outer, carrying apically 3 small and 1 long setae, outer flagellum with 7 aesthaetes and 1 seta; A2 (Fig.9,c) exopod with 20 to 22 plumose setae and 1 distolateral spine; endopod 4 segmented, distal segment with 5 minute setae; Md (Fig.9,d) palp fairly big, a constriction developed at about 2/3rd from proximal region, a small seta present near this constriction; no appreciable change in Mx1 (Fig.9,e); Mx2 (Fig.9,f) exopod with 27 to 29 setae; no appreciable change in Mxp1 (Fig.9,g), Mxp2 (Fig.9,h), Mxp3 (Fig.9,i); P1 to P3 chela well developed, exopod shorter than endopod (Fig.9,j), 3rd segment with 2 setae on distal outer margin; P4 and P5 (Fig.9,k) endopod longer than exopod, 3rd segment with 2 setae on outer distal margin; endopod of uropod with 18 plumose setae (Fig.9,m), exopod with 17 plumose setae, 1 nonplumose seta and 1 distolateral spine (Fig.9,n).

INTERMEDIATE STAGE I

MTL: 3.2 mm (3.16-3.33 mm); MCL:0.94 mm (0.91-1.09 mm).

This substage resembles the mysis stage in all respects except in the following respects: (1): pleopods 1 to 3 with 8 setal rudiments (Fig.10,d) and pleopods 4 & 5 with 3 to 4 well developed setae in addition to 4 to 5 setal rudiments, (2) Md (Fig.10,c) retain the free standing teeth, (3) telson more convex distally (Fig.10,f). Duration of this substage was 24 to 36 hours.

INTERMEDIATE STAGE II

MTL; 3.0 mm (2.9-3.1 mm); MCL: 0.94 mm (0.91-0.98 mm).

This substage bears a closer resemblance to postlarval stage than to mysis stage; presence of exopod with plumose setae on Mxp3 and P1 to P5 distinguishes this stage from postlarval stage.

Rostrum short with 3 dorsal teeth, distomedian spine on 5th abdominal segment absent (Fig.10,g); pleopods with 9 plumose setae (Fig.10,l); telson convex posteriorly bearing 7+7 spines; A2 (Fig.11,a) exopod wtih 23 to 24 plumose setae; endopod 6 segmented, distal segment bears 6 short setae apically; Md

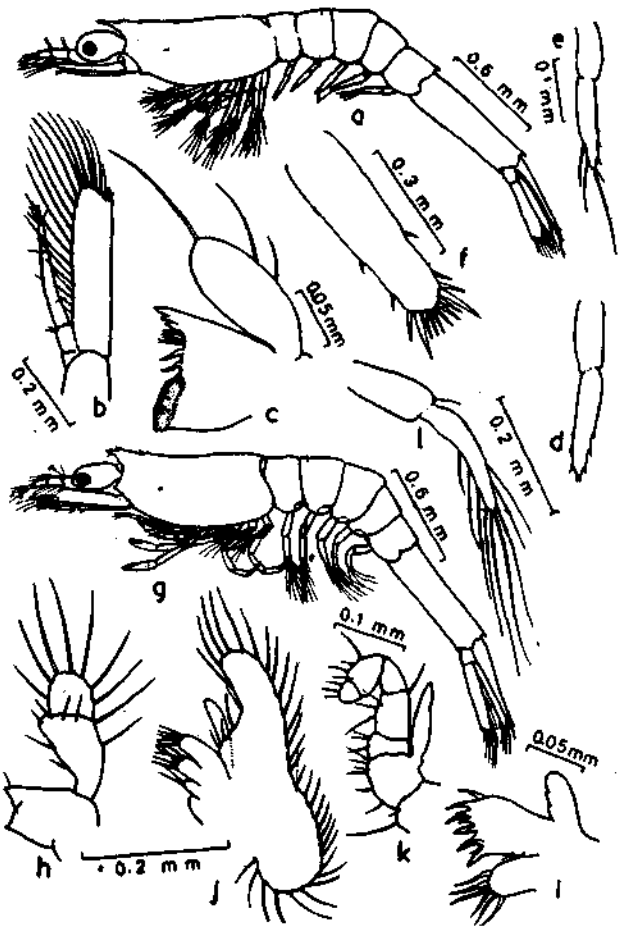

Fig. 10 *Metapenaeus affinis;* Intermediate I: a - lateral view; b - A2; c - Md; d - pleopod II; e - pleopod IV; f - telson. Intermediate II: g - lateral view; h - Md. i - Mx1; j - Mx2; k - Mxp2; l - pleopod III.

(Fig.10,h) with standing teeth absent, palp 2 segmented, proximal segment longer, both segments with plumose setae; Mx1 (Fig.10,i), setae on segments of endopod lost, distal endite of protopod with 12 setae and proximal endite with 6 setae; Mx2 (Fig.10,j) exopod with 35 setae, endopod reduced without segmentaion and setae, number of setae on endites of protopod reduced; Mxp1 (Fig.11,b) endopod without segments, reduced, only 2 small setae present on inner side, gill rudiment large, protopod broader, exopod with fewsetaedistally; Mxp2 (Fig.10,k) endopod recurved, exopod

reduced, without setae; Mxp3 (Fig.11,c) exopod short with 6 setae apically, setae on endopod reduced in length; P1-P3 (Fig.11,d) endopod 5 segmented, chela fully developed, exopod

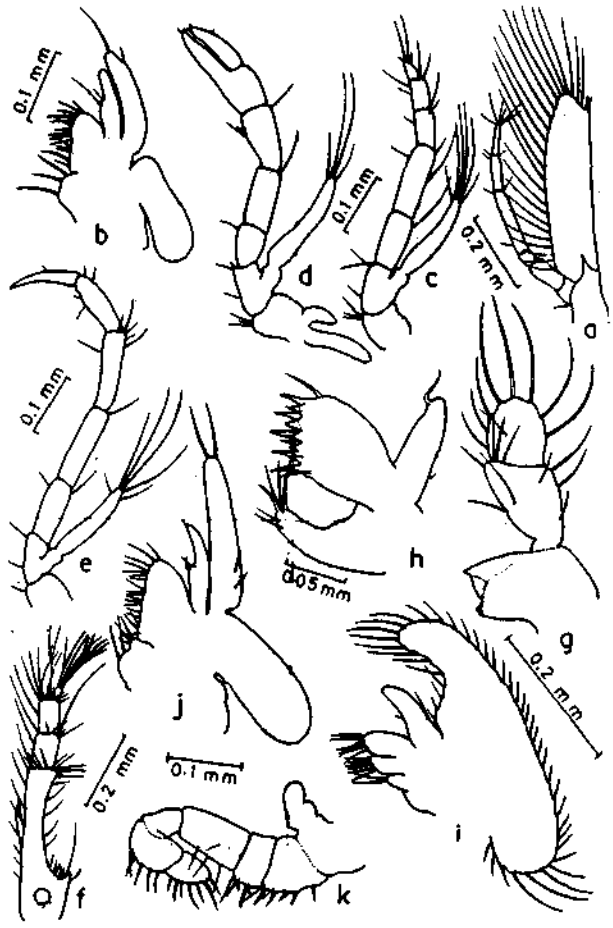

Fig. 11 *Metapenaeus affinis:* Intermediate II: a - A2; b - Mxp1; c - Mxp3; d - P1; e - P4; Postlarva I: f - A1; g - Md; h - Mx1: i - Mx2; j - Mxp1; k - Mxp2.

reduced, with plumose setae apically; P4 and P5 exopod reduced (Fig.11,e) bearing plumose setae apically, Duration of this substage was 24 to 36 hours.

POSTLARVA I

MTL: 3.3 mm (3.2-3.4mm); MCL: 0.94 mm (0.91-1.01 mm).

Rostrum short, sharply pointed with 3 dorsal spines; A1 inner flagellum longer than outer and faintly divided into 2, outer flagellum 2 segmented carrying 8 aesthaetes (Fig.11,f;) A2 (Fig.12,b) endopod 6 segmented, exopod with 23 to 24 plumose setae; Md (Fig.11,g) palp bigger than Md, number of setae increased, Mx1 (Fig.11,h) endopod small without segments, bearing terminally on inner side one seta, distal endite of protopod more flattened bearing 13 setae of which 1 is plumose; Mx2 (Fig.11,i) exopod with more than 40 setae, endopod reduced without segmentation, protopod with 4 endites, distal 2 endites with

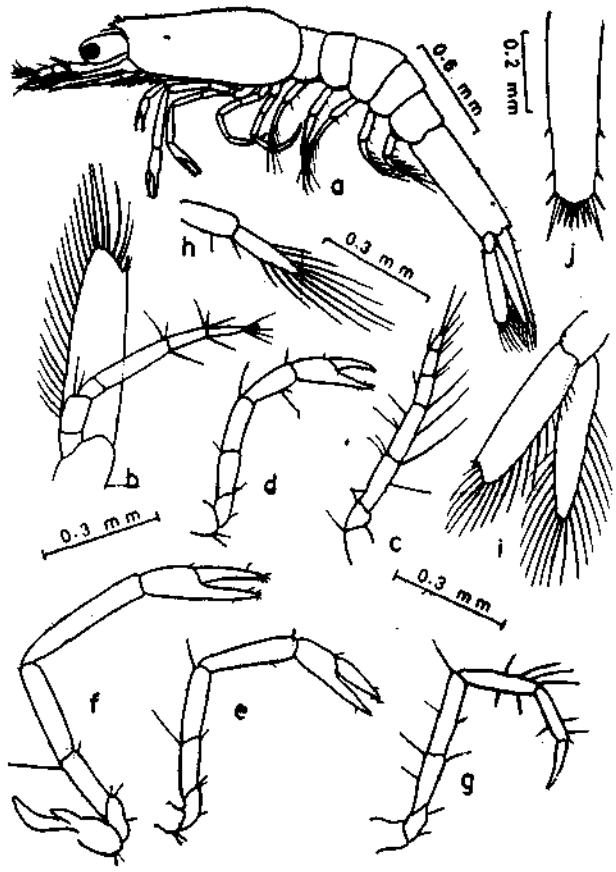

Fig. 12 *Metapenaeus affinis:* Postlarva I: a - lateral view; b - A2; c - Mxp3; d - P1: e - P2; f - P3; g - P4; h - pleopod: i - uropod: j - telson.

6 setae; Mxp1 (Fig.11,j) exopod with 2 short plumose setae distally and proximally endopod reduced, without segmentation, with 2 short seta on inner side, gills large, protopod broader with a number of setae on inner margin; Mxp2 (Fig.11,k) exopod shrunken, endopod sharply recurved, distal 2 segments carrying naumber of stout setae; Mxp3 (Fig.12,c) exopod absent; P1 to P3 (Fig.12,d,e,f) chela fully developed, exopod absent; exopod absent in P4 and P5 (Fig.12,g); uropod (Fig.12,i) exopod with 17 to 19 plumose setae, 1 nonplumose se a

and 1 distolateral spine, endopod with 19 to 20 setae, telson convex posteriorly (Fig.12,j).

DISCUSSION

The eggs of *M. affinis* (Fig.1,a) are 0.25 to 0.27 mm in diameter with the yolk mass measuring 0.21 to 0.22 mm. However, Thomas *et al.*, have reported smaller eggs for *M. affinis* (0.23 to 0.25 mm) and an unusually smaller yolk mass (0.14 mm).

Although Thomas *et al*[3]., have also described 6 nauplius substages, the setation of the appendages is at variance with our observations. The A1 is depicted by Thomas *et al*[3]., with 3 terminal and 2 inner lateral setae in the first three nauplius substages; we have consistently observed 3 inner lateral setae and an outer lateral seta, in addition to the terminal setae, in our material. Further, Thomas *et al.*,[3] have shown 7 setae on exopod of A2 of N I-N III while we have observed only 5 setae in N I, the number increasing with each naupliar moult (Fig.1,b.) Thomas *et al.*,[3] have reported that the number of setae of A1 and A2 remain constant in the first 3 naupliar stages. This is never the case in all the 6 penaeid species that we have reared in the laboratory.

On the inner lateral and distal aspect of A2 exopod, Thomas *et al*[3]., have shown only 9 setae in protozoea I and II seate in protozoea II and III, whereas in our material the A2 exopod possesses 10 setae on the inner lateral and distal aspect in all the 3 protozoea substages. In the A2 endopod we found 1+2+3 inner lateral setae in all the protozoea substages (Fig.2,a; 3,c; 4,a) while Thomas *et al.*,[3] have shown only 1+2 lateral setae in protozoea I and 1+2+2 in protozoea II and III.

Thomas *et al.*,[3] have shown 5 exopod setae in Mxp2 of protozoea I and 8 and 9 exopod setae in Mxp1 and Mxp2 respectively in protozoea III. But in our material the exopods of Mxp1 and Mxp2 show the following setation pattern during the protozoea stages:

	Exopod of Mxp1	Exopod of Mxp2
Protozoea I	7	6
Protozoea II	7	6
Protozoea III	9	7

The endopod rudiment of Mxp3 in protozoea III is tipped with 2 setae in our material (Fig. 3,j), while Thomas *et al.*,[3] have shown 3 terminal setae in the endopod rudiment of Mxp3.

A very important character which has been overlooked by Thomas *et al.*[3], is the rostral "platform" in protozoea II and III. In the present material a rostral "platform" is seen between the rostral tip and the supraorbital spinces in the dorsal view of the carapace (Fig.3,a;4,a)

The description of mysis I of *M. affinis* by Rao[2] differs from ours in the following respects:-

	Present work	Rao[2]
Al scale	11 setae	9 setae
Endopod of Mx1	5 terminal setae	3 terminal setae
Exopod of Mx2	9 setae	5 setae
Endopod of Mxp1	4 segmented	5 segmented
Exopod of Mxp1	7 setae	5 setae
Endopod of Mxp2	4 segmented	5 segmented
Exopod of Mxp2	6 setae	5 setae

The setation and segmentation pattern of the appendages of mysis I illustrated by us and indicated above is consistent and applicable to all the *Metapeaneus* spp. studied by us.

During the present study of *M. affinis* it was observed that the rostrum of the early mysis substages (mysis I and II) reaches beyond the eye as described by Rao[2] but in the later mysis substages the rostrum becomes shorter, falling short of the anterior end of eye.

Although Rao[2] and Thomas *et. al.*[3] have found only 3 mysis substages, during the present study 5 mysis substages could be distinguished on the basis of increase in the number of setae in the appendages and increase in length of the larvae and of the pleopod buds. Some of the last mysis larvae appear to moult into one of the intermediate substages described in this paper, before metamorphosing into postlarva I.

The postlarval stage of *M. affinis* is very similar to that described by Mohamed *et al.*[1], but the description of the rostral spines given by Mohamed *et. al.*[1], is not clear. They mention about 2 large teeth and 2 smaller spines. In the present material the 1st postlarval stage was found to possess 2 rostral teeth and 1 epigastric tooth. The smaller spines found in between the teeth and posterior to the epigastric, are not to be confused with the rostral teeth; they are minute moveable spines while the rostral teeth are large and fixed.

VII

Larval development — *METAPENAEUS MONOCEROS* (FABRICIUS)

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Metapenaeus monoceros was reared from the egg to the postlarval stage in the laboratory at Narakkal. At the rearing temperature of 25.2° C to 27.0° C the viable eggs take 15-17 hours to hatch out; the duration of the nauplius stage is 44 to 60 hours; the protozoea takes 5½ to 7½ days to develop to mysis 1; the mysis stage lasts for 9 to 12 days. Complete development from egg to postlarva 1 takes 17 to 23 days. The larvae pass through 6 nauplius substages, 3 protozoea substages, and 6 mysis substages before reaching postlarva 1. All the larval stages are described and illustrated in detail and compared with the earlier larval descriptions on this species.

Metapenaeus monoceros, a commercially important penaeid prawn has spawned in the laboratory at Narakkal on a number of occasions and the larvae have been successfully reared to the juvenile stage. The larval development of *M.monoceros* differed significantly in some respects from the earlier descriptions of the larvae of *M.monoceros* given by Mohamed *et.al.,* (1968, *FAO Fish.Rep.*,57(2): 487-503)[1], Raje and Ranade (1972, *J. Indian Fish. Ass;* 2: 30-46)[2] and Rao (1974, *J. mar. biol. Ass. India,* 15(1) : 95 - 124)[3]. In this paper the larval characters of *M.monoceros* are fully illustrated to bring out the exact nature of setation of the appendages. The temperature of the water in the rearing basins was 25.2°C-2.70° C and the salinity 33.2 - 34.6 ppt.

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DESCRIPTION OF DEVELOPMENTAL STAGES

EGGS

Opaque, having a diameter of 0.28 mm; the diameter of yolk 0.22 mm (fig.1a). Embryonic development took 15-17 hours.

NAUPLIUS I

MTL : 0.27 mm (0.26-0.28 mm); MW: 0.14 mm (0.14-0.15mm); MFS: 0.07 mm

Pear shaped unsegmented body, anterior region broad bearing an ocellus, posterior end rounded bearing a pair of furcal setae (Fig.1b), a small denticle present at median posterodorsal aspect of body; A1 uniramous, inner margin bears 3 small setae, outer distal margin with one long setae and apex with 2 long setae and small spike-like setae; A2 biramous, exopod with 5 long setae along inner and distal margin and a rudimentary seta on outer distal aspect, endopod shorter than exopod bearing

terminally one rudimentary and 2 long setae and 2 small lateral setae on inner margin; Md biramous, each ramus bearing 3 long setae distally all setae nonplumose. Duration of this substage was 3-4 hours.

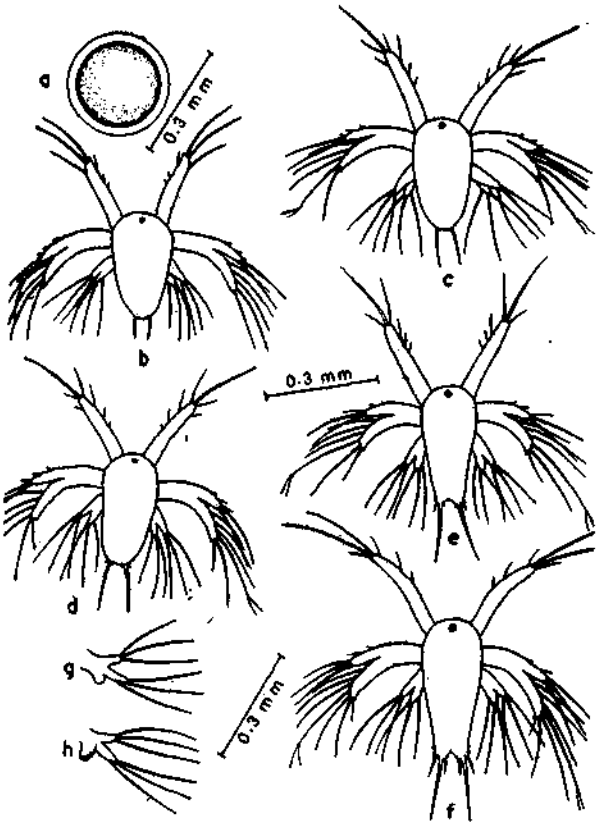

Fig. 1 *Metapenaeus monoceros* a - Egg; b - Nauplius I; c - Nauplius II; d - Nauplius III; e - Nauplius IV; f - Nauplius V; g - Md of nauplius V; h - Md of nauplius VI.

NAUPLIUS II

MTL: 0.28 mm (0.28-0.29 mm); MW: 0.15 mm MFS: 0.08 mm

A1 with 3 setae on inner margin, 3 setae apically of which middle one is the longest, and a small seta on distal outer margin; A2, 4th inner lateral seta of exopod, counting from the proximal end bifurcate at tip, this split condition is retained in all subsequent nauplius substages; no change in Md; all long setae of appendages plumose (Fig.1,c). Duration of this substage was 3-4 hours.

NAUPLIUS III

MTL: 0.28 mm (0.28-0.29 mm); MW:0.15 mm MFS: 0.10 mm (0.09-0.11 mm).

Furcal setae 3+3; exopod of A2 with 6 long plumose setae along inner and distal margin and one small spike-like seta at outer tip, endopod apically bearing one short and 2 long plumose setae; no change in A1 and Md (Fig.1d). Duration of this substage was 6-8 hours.

NAUPLIUS IV

MTL: 0.30 mm (0.29-0.31 mm); MW: 0.15 mm MFS: 0.13mm

Furcal lobes distinct, each with 4 setae A1 apically bearing 3 plumose setae of which outer is the smallest, 3 setae present on inner margin, outer distal seta absent; exopod of A2 bearing 8 setae of which proximal and distal ones small and spike like (Fig.1,e); protopod of Md shows slight swelling. Duration of this substage was 6-8 hours.

NAUPLIUS V

MTL: 0.36 mm (0.35-0.36 mm); MW: 0.16 mm (0.15-0.17 mm); MFS: 0.16 mm (0.15-0.17mm).

Furcal lobes distinct, bearing 6+6 setae; A1 apically with 3 setae of which 2 are almost of same length (Fig.1,f); endopod of A2 with 3 long plumose setae apically and 2 short setae on inner side, exopod with 9 setae of which proximal and distal ones are rudimentary (Fig.1,f); swelling on the protopod of Md clearly seen (Fig.1,g). Duration of this substage was 10-12 hours.

NAUPLIUS VI

MTL: 0.39 mm (0.38-0.41 mm); MW: 0.21 mm (0,20-0. 22mm); MFS: 0.17mm.

Body elongated, frontal organs developed, carapace demarcated, furcal lobes with 7+7 setae (Fig.2,a); developing buds of Mx1, Mx2, Mxp1, Mxp2 and Mxp3 clearly seen; A1 indistinctly segmented proximally 3 setae present on inner margin, 1 rudimentary seta and 2 long plumose setae apically, 4 setae, 1 very small seta and 3 aesthaetes present on distal outer margin; A2 endopod bearing apically 4 setae of which 3 are long and plumose, 1+2 setae present on inner margin; exopod carrying 8

long plumose setae and 2 rudimentary ones (Fig.2,a); Md further developed, outline of cutting edge of Md clearly seen inside swelling (Fig.1,h). Duration of this substage was 16-24 hours.

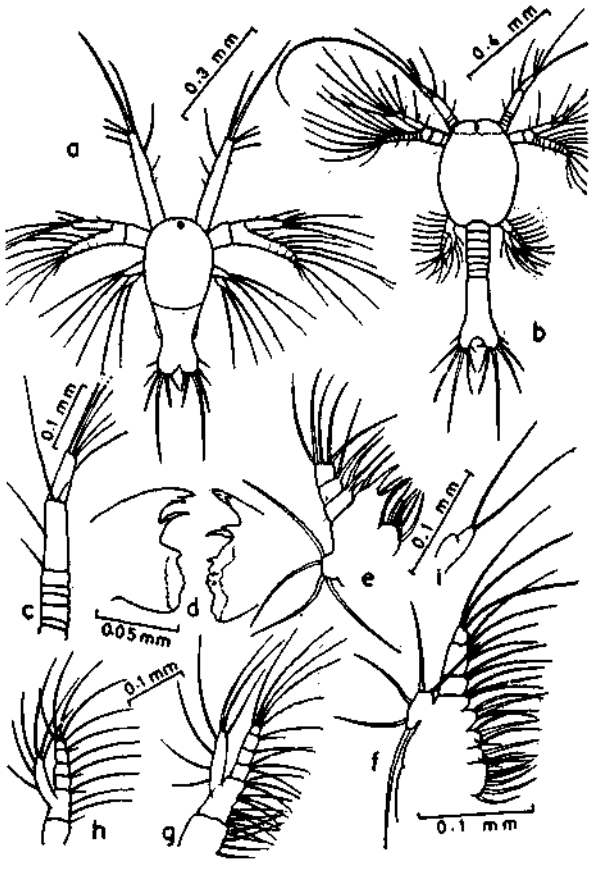

Fig. 2 *Metapenaeus monoceros:* a - Nauplius VI; Protozoea I; b - dorsal view; c - A1; d - Md; e - Mx1; f - Mx2; g - Mxp1; h - Mxp2; i - Mxp3.

PROTOZOEA I

MTL: 0.83 mm (0.80-0.85 mm); MCL; 0.37 mm (0.37-0.38 mm).

Carapace rounded anteriorly with a median notch, ocellus persists, developing compound eye seen through carapace, frontal horns minute smaller than frontal crgans; caudal lobes with 7+7 setae.

A1 (Fig.2,c) uniramous, 3 segmented, basal segment subdivided into 5, middle segment with 2 lateral setae and 2 distal setae, distal segment with 3 setae and 3 aesthaetes, 1 of the setae very long; A2 biramous, endopod 2 segmented, bearing 5 setae apically of which 4 are long and plumose and one short and nonplumose, proximal segment with 1+2+3 setae on inner margin, exopod 10 segmented bearing 10 setae along inner and distal margin and 2 setae along outer margin; Md (Fig.2,d) exopod and endopod absent, almost symmetrical, right and left Md each with one free standing tooth; Mx1 (Fig.2,e) protopod with 2 lobes, distal with 4 and proximal with 7 setae, endopod 3 segmented, distal segment apically bearing 5 long setae, 1st and 2nd segments with 3 and 2 setae respectively, exopod small, knob like bearing 4 long feathery setae; Mx2 (Fig.2,f) protopod with 5 lobes, proximal lobe rounded bearing 7 to 8 setae, other lobes with 3 to 4 setae, endopod 4 segmented, the segmentation between 2nd and 3rd indistinct, distal segment with 3 setae and other segments each with 2 long setae on inner margin, exopod with 5 long feathery setae; Mxp1 (Fig.2,g) biramous' protopod 2 segmented, proximal and distal segments with 5 and 12 setae respectively, endopod 4 segmented, 1st, 2nd and 3rd segments carrying 3, 1 and 2 setae on inner margin, distal segment with 5 long plumose setae apically, exopod unsegmented bearing 7 long plumose setae; Mxp2 (Fig.2,h) shorter than Mxp1, protopod 2 segmented, endopod 4 segmented, 1st, 2nd and 3rd segments with 2, 1 and 2 setae along inner margin, distal segment carrying apically 5 long plumose setae, exopod unsegmented with 6 long plumose setae; Mxp3 (Fig.2,i) not fully developed biramous, exopod with 2 long plumose setae, endopod bare. Duration of this substage was 48-60 hours.

PROTOZOEA II

MTL: 1.5 mm(1.41-1.64 mm); MCL: 0.59 mm.

Rostrum and stalked eyes developed, supraorbital spine present, between base of rostrum and supraobital spines there is a rostral platform whose anterolateral corners are produced into sharp spines; abdomen 6 segmented (Fig.3,a), telson not demarcated from last abdominal segment; no appreciable change in A1 and A2; Md (Fig.3,b)asymmetrical with 5 free standing teeth present in left Md and 1 in right Md; Mx1 distal protopod lobe with 7 setae; 1 more inner lateral seta added to 2nd segment of

endopod of Mxp1; Mxp3 exopod with 3 long plumose setae(Fig.3,c). Duration of this substage was 48-60 hours.

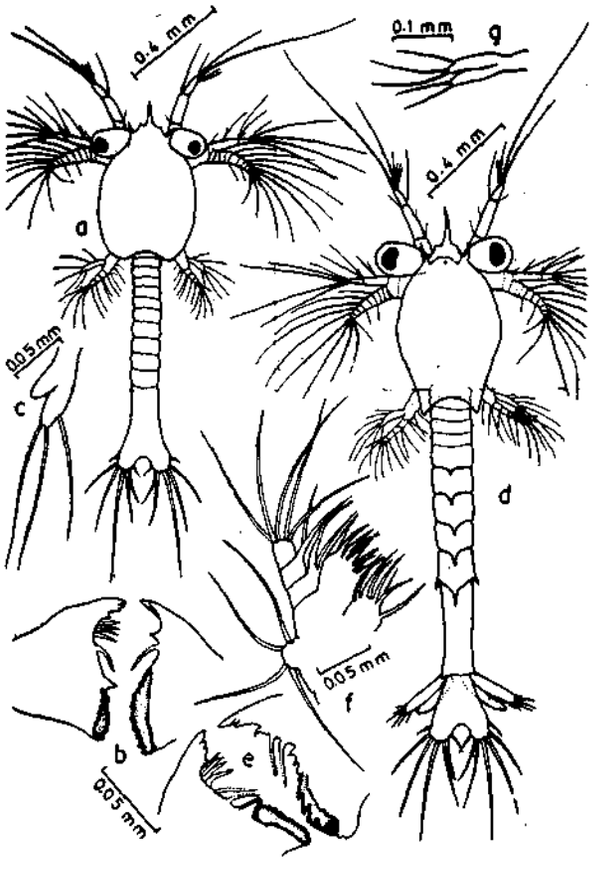

Fig. 3. *Metapenaeus monoceros:* Protozoea II. a - dorsal view; b - Md: c - Mxp3: Protozoea III: d - dorsal view; e - Md; f - Mx1: g - Mxp3.

PROTOZOEA III

MTL: 1.69 mm (1.92-2.99 mm): MCL: 0.72 mm (0.71-0.74 mm).

1 to 5 abdominal segments each with a posterodorsal spine (Fig.3,d), 5th segment with posterolateral spines, each lobe of telson with 7 setae, uropod biramous, exopod with 6 short nonplumose setae distally; A1 3 segmented, the subdivisions of basal segment absent, distal segment with 3 aesthaetes and 3 setae; A2 same as in the previous stage; left Md with 6 and right Md with 2 free standing teeth in between incisor and molar processes (Fig.3,e) Mx1 (Fig.3,f) distal lobe of protopod with 8-9 setae; Mx2 number of setae on protopod lobes increased; Mxp1 exopod wiih 6 plumose setae; Mxp2 exopod with 9 plumose setae; Mxp3 (Fig.3,g) not fully developed, exopod and endopod with 3 and 2 setae distally. Duration of this substage was 36-60 hours.

MYSIS I

MTL: 2.4 mm (2.37-2.45 mm); MCL; 0.86 mm (0.84-0.87 mm).

Rostrum extends beyond eye, devoid of teeth, carapace with pterygostomial and antennal spines, 5th and 6th abdominal segments with dorsal median spine, 6th abdominal segment with a prominent ventral median spine on posterior end (Fig.4,a).

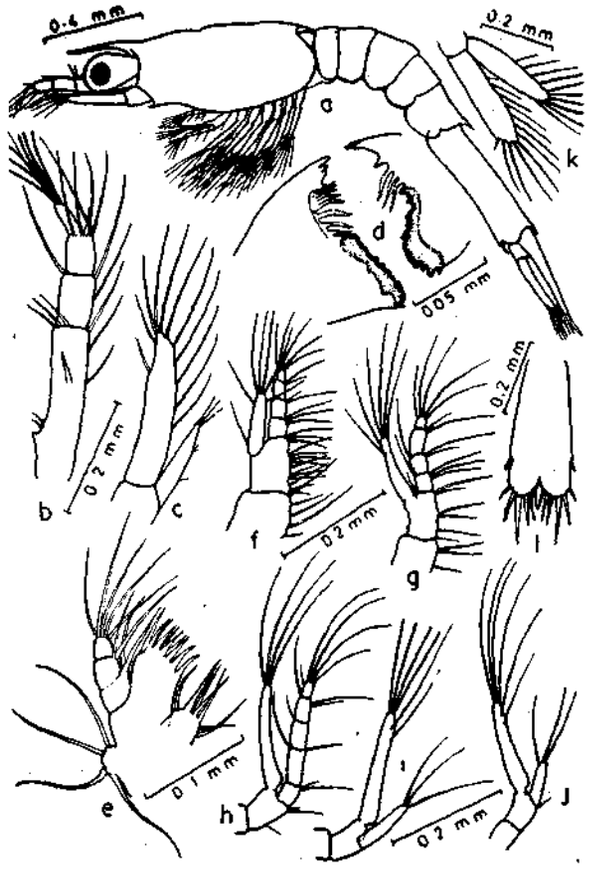

Fig. 4 *Metapenaeus monoceros:* Mysis I: a - lateral view; b - A1: c - A2; d - Md; e - Mx1; f - Mxp1; g - Mxp2; h - Mxp3; i - P1; j - P5; k - uropod; l - telson.

A1 (Fig.4,b) 3 segmented, proximal segment with a prominent ventral spine, plumose setae present on junction of segments and on inner side, distal segment bearing 2 flagellar rudiments inner one small, bud-like, bearing 2 setae; outer unsegmented bearing 6 aesthaetes and 1 seta

A2 (Fig.4,c) exopod unsegmented, scale like, bearing 10 setae along inner and distal margin and 1 seta on distolateral angle, endopod half length of exopod, bearing 3 short setae apically, and 1+2 setae on inner margin; Md (Fig.4,d) with 8 free standing teeth on left Md and 3 on right Md; Mx1 (Fig.4,e) proximal and distal endites of protopod with 7 and 10 setae respectively, endopod 3 segmented, distal segment with 5 setae, 1st and 2nd segments with 2 to 3 and 2 setae respectively, exopod with 4 feathery setae; exopod of Mx2 (Fig.5,a) with 9 plumose setae; Mxp1 (Fig.4,f) exopod with 7 plumose setae; Mxp2 (Fig.4,g) exopod with 4 apical and 2 subapical plumose setae, endopod 4 segmented, 1st and 2nd segments carrying 1 seta on outer margin; Mxp3 (Fig.4,h) biramous, fully developed, protopod 2 segmented, exopod with 4 long plumose setae apically, endopod 5 segmented, distal segment with 1 short and 4 long plumose setae, 1st, 2nd and 4th segments carrying 2, 1 and2 inner lateral setae respectively, outer distal margin of 2nd, 3rd and 4th segments with 1 seta each; P1 to P5 almost identical (Fig.4,i&j), endopod unsegmented carrying terminally 3 long setae, exopod unsegmented, bearing 4 apical and 4 subapical plumose setae; uropod (Fig.4,k) biramous, exopod with 1 short nonplumose outer seta and 11 long plumose setae; endopod with 10 plumose setae; telson (Fig.4,l) broader distally with deep median cleft carrying 7+7 setae. Duration of this substage was 36-48 hours.

MYSIS II

MTL; 2.50 mm(2.38-2.55 mm);MCL: 0.87 mm (0.84-0.90 mm).

Rostrum with a dorsal tooth, pleopod buds still absent (Fig.5,b). telson almost rectangular, median cleft reaching only to level of origin of penultimate pair of lateral setae, carrying 7+7 setae (Fig.5,k);

A1, number of setae on segments increased, inner flagellum reaching 2/3rd of outer flagellum; A2 (Fig.5,c) exopod with 14 plumose setae and 1 distolateral spine; Md (Fig.5,d) rudimentary palp developed, left and right Md with 7-8 and 3 standing teeth respectively; Mx2 exopod (Fig.5,f) with 11 plumose setae; Mxp1 (Fig.5,g) proximal and distal segments of protopod with 8 and 14 setae respectively on inner side, 1st segment of endopod with 1 seta on outer side, exopod with 7 plumose setae, a few fine hair like setae seen on proximal outer margin of exopod; Mxp2 endopod 5 segmented, with 6 setae on the distal segment, outer distal margin of 3rd segment with a seta; Mxp3 same as in previous stage; P1 to P3 (Fig.5,h) identical, endopod indistinctly segmented, distal segment with 3 long setae terminally, and a long seta on outer

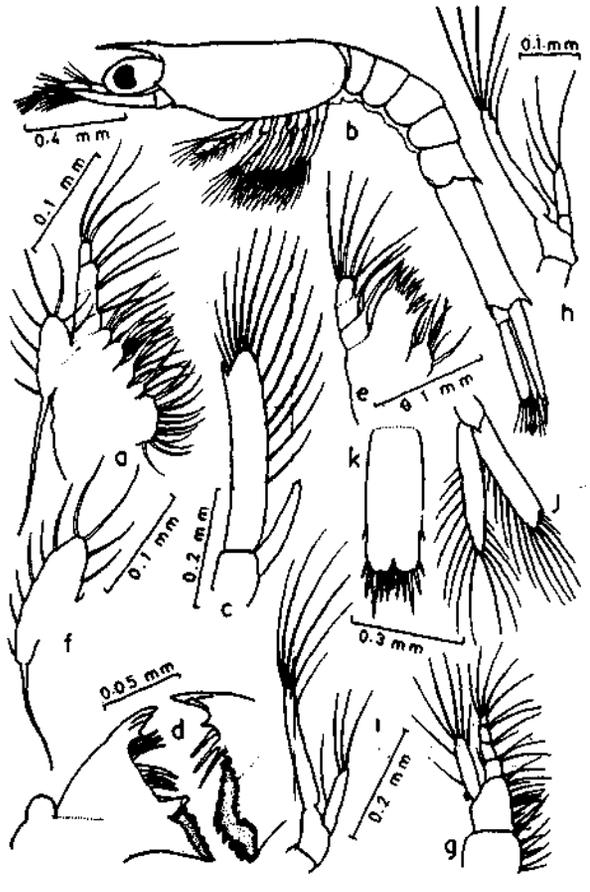

Fig. 5 *Metapenaeus monoceros:* Mysis I: a - Mx2; Mysis II; b - lateral view; c - A2; d - Md; e - Mx1; f - exopod of Mx2; g - Mxp1; h - P1; i - P5; j - uropod; k - telson.

margin, in some specimens a cleft on distal segment indicating the developing chela seen; P4 and P5 (Fig.5,i) endopod indistinctly 2 segmented; uropod (Fig.5,j) exopod with 14 to 15 plumose setae, 1 nonplumose seta and 1 short spine distolaterally. Duration of this substage was 36-48 hours.

MYSIS III

MTL: 2.7 mm (2.58-2.81 mm); MCL: 0.95 mm (0.92-0.98 mm).

Rostrum with 2 dorsal teeth (Fig.6,a), in some specimens a small hepatic spine seen; pleopod buds small and unsegmented. A1 (Fig.6,b) inner flagellum more than half of outer flagellum bearing at its apex 2 setae of which 1 is very long, outer flagellum unsegmented bearing 5 aesthaetes and 1 seta, A2 (Fig 6,c) endopod unsegmented not reaching half length of exopod, exopod

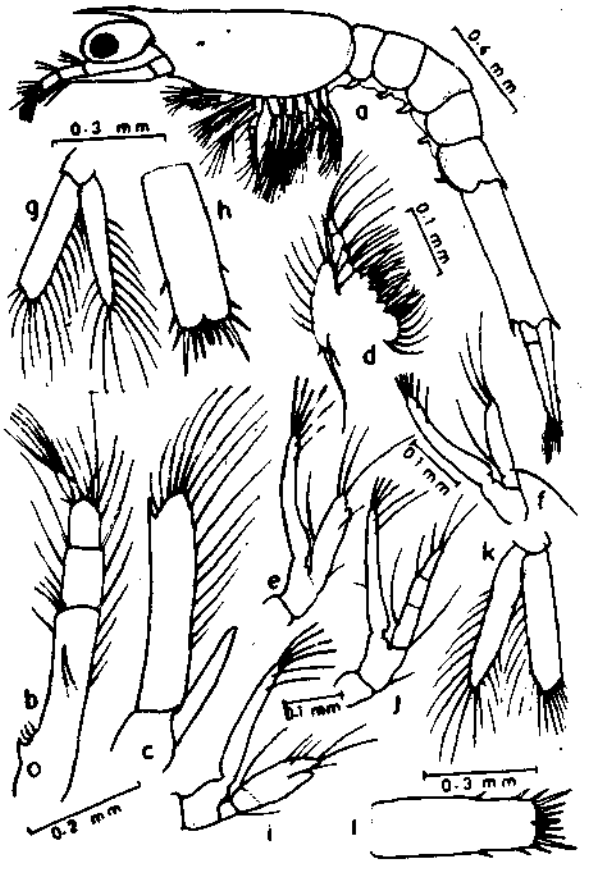

Fig. 6 *Metapenaeus monoceros:* Mysis III: a - lateral view: b - A1: c - A2; d - Mx2: e - P1: f - P5: g - uropod: h - telson. Mysis IV: i - P1; j - P5: k - uropod: l - telson.

with 16 plumose and setae and 1 distolateral spine, Mx2 (Fig.6,d) exopod with 13 plumose setae; P1 to P3 almost identical (Fig.6,e) cleft of developing chela clearly seen; P4 and P5 identical (Fig.6;f) endopod indistinctly segmented, 1st segment bearing 1 long inner seta and 2nd with 1 long outer seta; endopod of uropod (fig.6,g) with 14 to 15 plumose setae; telson (Fig.6,h) rectangular; distal cleft small bearing 7+7 setae. Duration of this substage was 36-48 hours.

MYSIS IV

MTL: 2.86 mm (2.83-2.90 mm); 0.95 mm.

Pleopod buds further developed but not segmented (Fig.7,a); flagella of A1 equal in length (Fig.7,b) inner flagellum bearing apically 1 long and 2 short setae, outer flagellum bearing 7 aesthaetes in 3 groups of 4+2+1 and 1 long seta, number of seta on segments increased; A2(Fig.7,c) endopod 2 segmented, faint indications of segnentation seen on distal

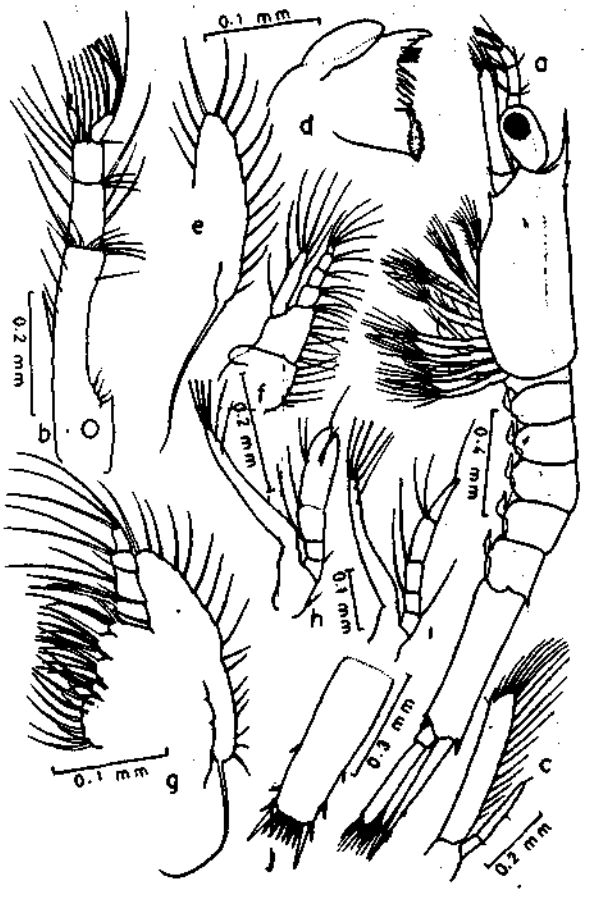

Fig. 7 *Metapenaeus monoceros:* Mysis IV: a - lateral view; b - A1; c - A2; d - Md; e - exopod of Mx2; f - Mxp1. Mysis V: g - Mx2; h - P1; i - P5; j - telson.

segment, exopod with 18 plumose setae and 1 spine; palp of Md developed into a finger shaped projection (Fig.7,d); exopod of Mx2 with 16 plumose setae (Fig.7,e); Mxp1 with a small bud like rudiment of gill (Fig.7,f); P1 to P3 (Fig.6,i) almost identical, anterior portion of endopod swollen showing developing chela and bearing 6 setae, P4 and P5 almost identical

(Fig.6,j) endopod indistinctly divided into 4 segments exopod of uropod (Fig 6,k) with 15 to 16 plumose setae, 1 nonplumose seta and 1 distolateral spine endopod with 16 plumose setae; telson with shallow cleft (Fig.6,l). Duration of this substage was 36-48 hours.

MYSIS V

MTL: 3.17 mm (2.99–3.28 mm); MCL: 1.10 mm (0.95-1.09 mm).

Pleopods 2 segmented (Fig.8,a); telson truncate posteriorly (Fig.7,j) bearing 3 pairs of lateral setae and 8 distal setae; A2 (Fig.8,b) exopod with 22 plumose setae and 1 spine,

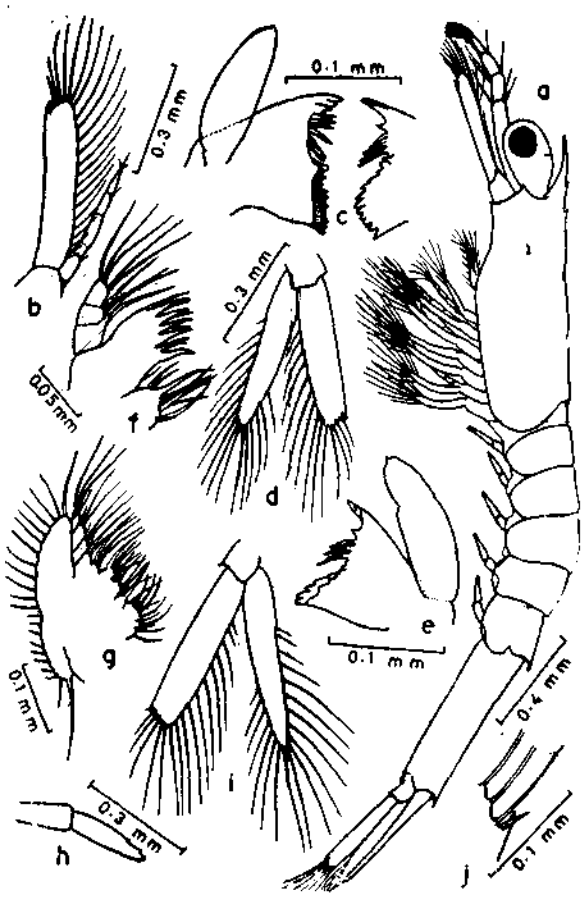

Fig. 8. *Metapenaeus monoceros:* Mysis v; a - lateral view; b - A2; c - Md; d - uropod. Mysis VI: e - Md; f - Mx1; g - Mx2; h - pleopod; i-uropod; j - distolateral tip of exopod of uropod.

endopod indistinctly 5 segmented, more than ½ length of exopod; Md (Fig.8,c), palp big, unsegmented, left and right Md with 6 to 7 and 3 free standing teeth respectively; Mx2 Fig. 7,g) exopod with 20 to 22 plumose setae; P1 to P3 almost identical in structure (Fig.7,h), endopod 4 segmented and bigger than exopod; P4 and P5 identical (Fig.7,i) endopod 5 segmented as long as exopod; endopod of uropod (Fig.8,d) with 17 to 18 plumose setae. Duration of this substage was 36-48 hours.

MYSIS VI

MTL: 3.15 mm (2.91-3.46 mm); MCL: 1.00 mm (0.94 mm 1.09mm).

Distally pleopods bear 4 to 5 projections indicating developing setae (Fig.8,h); Md (Fig 8,e) palp fairly big with a constriction at about 2/3rd from proximal end; chela of P1 to P3 fully developed; telson convex posteriorly (Fig; 9,h); A2 (Fig.9,b) exopod with 21 plumose setae and 1 distolateral spine, endopod with 5 short setae apically; Mxp1 (Fig. 9,c) gill rudiment fairly developed; Mxp2 (Fig.9,d) endopod 5 segmented, distal segment with 6 long plumose setae, 1st 3 segments carrying 1 seta on outer

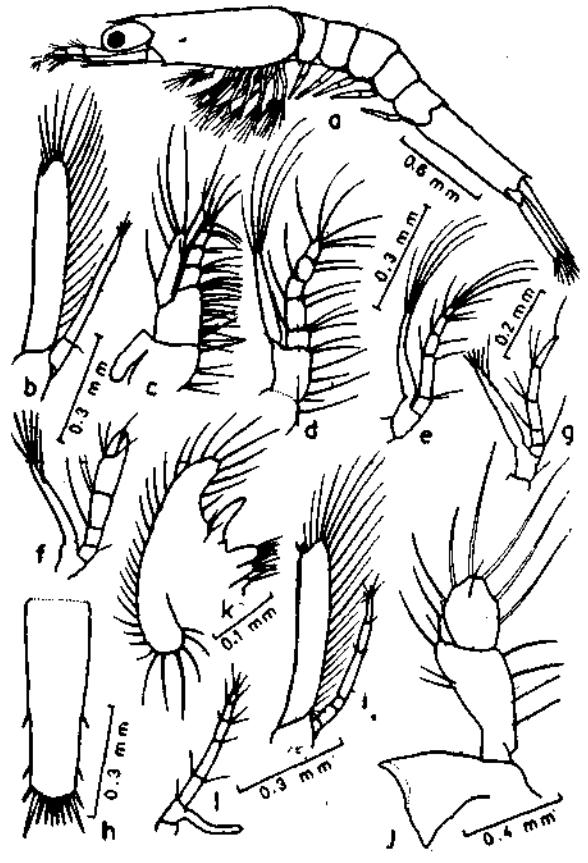

Fig. 9 *Metapenaeus monoceros:* Mysis VI: a - lateral view; b - A2; c - Mxp1; d - Mxp2; e - Mxp3 f - P1; g - P5; h - telson. Postlarva I: i - A2; j - Md; k - Mx2; l - Mxp3,

distal margin, exopod shorter than endopod; Mxp3 (Fig.9,e) endopod 5 segmented, longer than exopod. distal segment with 5 plumose setae; P1 to P3 (Fig.9,f) endopod 5 segmented chela fully developed, exopod shorter than endopod, P4 and P5 (Fig.9,g] endopod 5 segmented, longer than exopod, distal segment with a long seta, 2nd, 3rd and 4th with 1, 2 and 2 outer distal setae; endopod of uropod with 19 plumose setae (Fig.8,i) exopod with 16 plumose setae, 1 short non-plumose seta and a distolateral spine (Fig.8,j). Duration of this substage was 36-48 hours.

POSTLARVA I

MTL: 3.02 mm (2.87-3.15 mm); MCL: 0.91 mm (0.91-0.92 mm).

Rostrum short with 3 dorsal teeth [Fig. 10,a); exopods of P1 to P5 reduced, without setae; pleopods functional bearing plumose setae (Fig.10,j]; A1 (Fig.10,b) inner flagellum longer

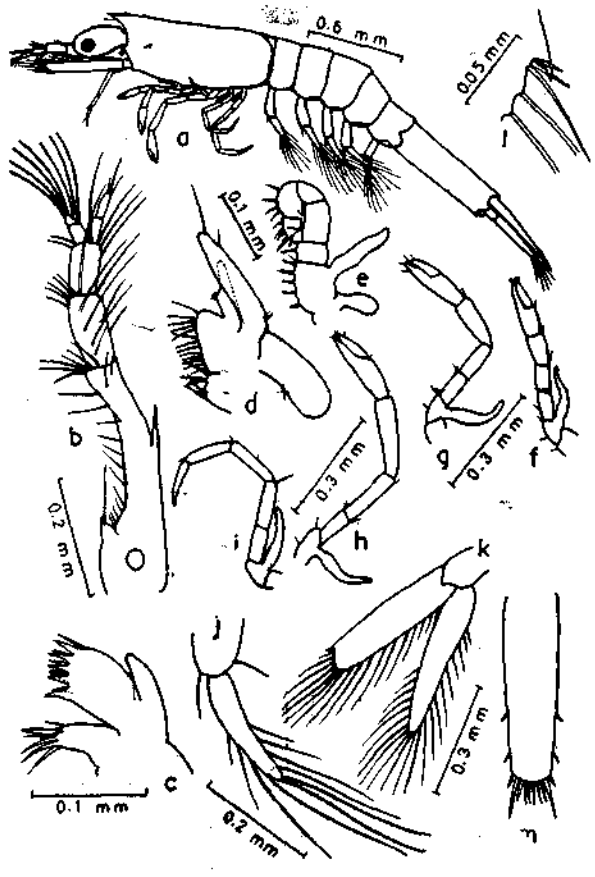

Fig. 10. *Metapenaeus monoceros:* Postlarva 1. a - lateral view; b - A1; c - Mx1; d - Mxp1; e - Mxp2; f - P1; g - P2; h - P3; i - P5 j - pleopod II ; k - uropod ; l - distolateral tip of the exopod of uropod ; m - telson.

than outer, 2 segmented bearing 3 setae apically, outer in 2 segmented bearing 7 to 8 aesthaetes, statocyst fully developed; A2 (Fig.9,i) exopod with 22 to 25 plumose setae, endopod 5 to 6 segmented and distal segment with 6 short setae apically; Md (Fig.9,j) palp big, flattened and 2 segmented carrying plumose setae, free standing teeth absent; Mx1 (Fig.10,c) endopod reduced, unsegmented and palp like, distal endites of protopod more flattened and bearing short stumpy setae proximal endite with long setae; Mx1 (Fig.9,k) exopod flattened, leaf like bearing 33 to 40 plumose setae, endopod unsegmented, without setae, protopod with 3 endites bearing small bristle - like setae apically; Mxp1 (Fig. 10, d) exopod bearing only 2 short setae distally and 2 short setae on proximal outer margin, endopod unsegmented bearing 2 small setae, protopod flattened with 2 lobes carrying number of setae, gill well developed; Mxp2 (Fig. 10,e) exopod unsegmented without setae, endopod sharply curved distally bearing a number of stout setae, protopod bearing short setae on inner side, rudimentary gills developed; Mxp3 (Fig.9,l) exopod reduced, endopod 5 segmented bearing a number of setae; P1 to P3 (Fig.10,f,g,h) exopod reduced without setae, endopod 5 segmented, chela fully developed, a progressive increase in length from P1 to P3 noticed; P4 and P5 (Fig.10,i) identical, exopod reduced, endopod 5 segmented; endopod of uropod (Fig.10,k) with 21-22 plumose setae, 2 short non-plumose setae and a distolateral spine (Fig.10,l); telson (Fig.10,m) convex posteriorly bearing 3 pairs of lateral setae and 8 distal setae.

DISCUSSION

The eggs of *M.monoceros* are 0.28 mm in diameter, the yolk mass measuring 0.22 mm. Raje and Ranade[2] have, however, recorded a larger size (0.35 mm) for the eggs of *M. monoceros*.

The six nauplius substages were observed during the present study. However, Raje and Ranade[2] found only five nauplius substages in the development of *M. monoceros*. The nauplius IV has not been described by them; their nauplius IV and nauplius V correspond to our nauplius V and nauplius VI respectively. In the following table the setation pattern of the nauplius substages observed by us is compared with that given by Raje and Ranade[2].

	Setation	
	Present observations	Raje and Ranade[2]
Nauplius I		
A1	2+i terminal	2 terminal
	3 inner lateral	2 inner lateral
	1 outer lateral	1 outer lateral
A2 exopod	5+i	5+i
A2 endopod	2+i terminal	2 terminal
	2 inner lateral	2 inner lateral
Nauplius II		
A1	3 terminal	2+i terminal
	3 inner lateral	2 inner lateral
	1 outer lateral	2 outer lateral
A2 exopod	5+1	6
Nauplius III		
A1	3 terminal	3+i terminal
	3 inner lateral	2 inner lateral
	1 outer lateral	1 outer lateral
A2 exopod	6+i	6
Nauplius IV		
A1	3 terminal	not described
	3 inner lateral	—do—
	no outer lateral	—do—
A2 exopod	1+6+i	—do—
Nauplius V		
A1	3 terminal	3 terminal
	3 inner lateral	3 inner lateral
A2 exopod	1+7+i	7
Nauplius VI		
A1	i+2 terminal	3 terminal
	3 inner lateral	3 inner lateral
	1 terminal aesthaetes	
	2 outer lateral aesthaetes	
A2 exopod	1+8+i	8+i
A2 endopod	4 terminal	3 terminal
	1+2 inner	2 inner

i respresents spike-like setal rudiment.

In our material the A1 bears 3 inner lateral setae in all the naupliar substages while Raje and Ranade[2] have shown only 2 inner lateral setae in Nauplius I to III. The relative length of the terminal setae and outer lateral setae of A1 undergo characteristic transformation in successive nauplius substages in all the penaeids studied by us. But this pattern is not seen in the illustrations given by Raje and Ranade[2]. The setation of A1 in the last nauplius substage illustrated by Raje and Ranade[2] is completelyatypical.

The setation of the protozoea substages of *M.monoceros* given by Raje and Ranade[2] closely resemble the pattern that was observed during the present study except in the following respects. The exopod of Mxp2 of protozoea I and II is shown with 5 setae instead of 6 setae as observed by us and the bud of Mxp3 of protozoea II is drawn with 2 setae at the tip of each ramus while we found only 3 setae in the outer ramus and none on the inner.

Raje and Ranade[2] described five mysis substages for *M.monoceros*. We found six mysis substages which could be distinguished on the basis of the increse in (i) length of the pleopod buds, (2) number of setae in the exopod of Mx2 and the scaphocerite and (3) total length of larvae. The fifth mysis substage described by Raje and Ranade[2] is actually equivalent to the "intermediate stage" observed by us in *M. dobsoni*. However, no "intermediate stage" was observed in *M.monoceros* during the present study.

The wide range in size of mysis II and III given by Rao[3] is suggestive of the fact that two or more substages may have been clubbed together under these two substages. The mysis substages described by Raje and Ranade[2] and Rao[3] for *M.monoceros* can be equated with the substages observed during the present study as follows:

Present Work	Raje and Ranade[2]	Rao[3]
Mysis I	Mysis I	Mysis I
Mysis II	... .	Mysis II
Mysis III	Mysis II	....
Mysis IV	Mysis III	....
Mysis V	.. ..	....
Mysis VI	Mysis IV	Mysis III

The setation of the mysis substages given by Raje and Ranade[2] is closely similar to the present observations except for the fact that the Md palp is shown as 2 segmented even in mysis III. In our material the Md palp becomes segmented only in the postlarval stage. Rao[3] has also shown an unsegmented Md palp in all the mysis substages described by him. Raje and Ranade[2] have depicted a pair of minute spines on the posterior margin of the 6th abdominal segment in the mysis substages. But these spines were not observed by us; we found a pair of very thin setae in this place.

The mysis I of *M.monoceros* described by Rao[3] is atypical in the following respects: (a) the terminal segment of the endopod of the Mx1 has 4 setae instead of 5, (b) the exopod of Mxp1 has 4setae instead of 5, and (c) the endopod of Mxp2 is 5 segmented with 4 terminal setae in the distal segment, whereas in all the penaeid larvae studied at Narakkal the endopod of this appendage is 4 segmented and has 5 setae on the distal segment. Rao[3] has also shown a lesser number of setae on the exopod of Mx2 in mysis II and III.

Rao[3] stated that the rostrum reaches the tip of eye or falls short of the eye in the mysis stage of *M.monoceros*. But during our present observations we found that the rostrum of mysis I reaches beyond the eye and gradually gets shortened in the subsequent mysis substages.

The first postlarva described by Mohamed *et. al.*[1] and Raje and Ranade[2] are similar in many respects to the present material. But Mohamed *et. al.*[1] have stated that an epigastric tooth is absent in postlarva I. It is clearly present in the present material. The two smaller rostral spines described by Mohamed *et. al.*[1] are not true rostral teeth but moveable spinelets. Rao[3] has shown a bluntly rounded rostral tip in the early postlarvae of *M.monoceros*. The rostrum is sharply pointed in our material. The blunt rostrum is characteristic of postlarva I of *M. dobsoni*.

VIII

Larval development — *METAPENAEUS BREVICORNIS* (H. MILNE EDWARDS)

G. Sudhakara Rao

Metapenaeus brevicornis spawned in the laboratory at Kakinada Research Centre of the Central Marine Fisheries Research Institute and the eggs were reared up to mysis I stage. The 6 nauplius substages, 3 protozoea substages and mysis I substage are described and illustrated in detail. At a rearing temperature of 29.2°C to 30.8°C the nauplii hatched out 9½ hours after spawning. The duration of the nauplius stage was 44 hours and protozoea stage 5 days.

Metapenaeus brevicornis, the yellow prawn, which is commercially important in West Bengal, Kakinada and Bombay, spawned during October 1978 in the laboratory of the Kakinada Research Centre of the Central Marine Fisheries Research Institute and the eggs were reared up to mysis I stage. The detailed structure and setation of the appendages of the various developmental stages are described and illustrated here. The temperature of the water in the rearing basins ranged from 29.2° C to 30.8° C and the salinity from 30.6 to 30.9‰.

The author is thankful to Dr. E. G. Silas Director, Central Marine Fisheries Research Institute, Cochin, for the encouragement and suggestions, and to Shri N. N. Pillai, who helped in the camera lucida drawings.

DESCRIPTION OF DEVELOPMENTAL STAGES

EGGS

Eggs are irregular or oval as soon as they are spawned but after 2 to 3 minutes assume a perfectly spherical shape. After fertilisation the vitelline membrane becomes separated from the cytoplasm of the egg and the perivitelline space is formed. The fertilised eggs measured from 0.28-0.29 mm in diameter with a yolkmass of 0.20-0.21 mm diameter. (Fig 1,a,b). Embryonic development, from spawning through cleavage, gastrulation and appendage formation, to hatching was closely observed and illustrated (Fig.1,b-h). Hatching process starts about 9 hours after spawning.

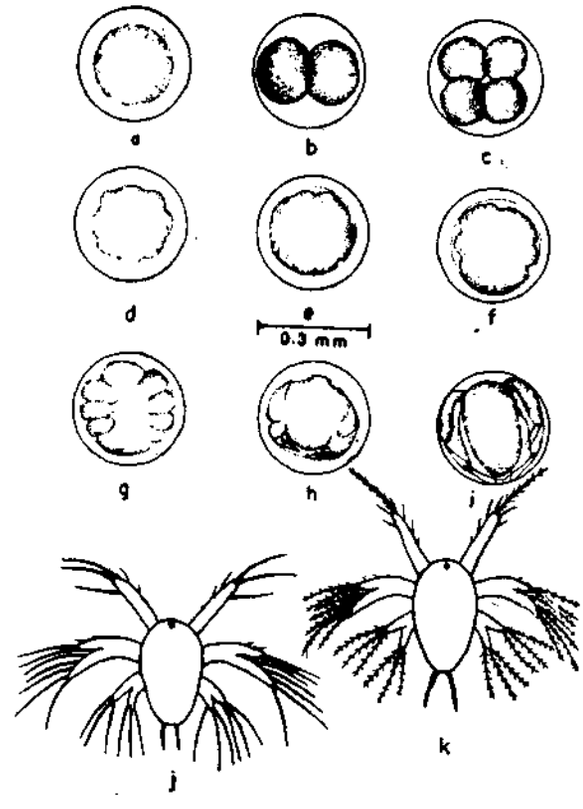

Fig. 1 *Metapenaeus brevicornis:* a - egg; b to i eggs on various stages of development; j - Nauplius I: k - Nauplius II.

NAUPLIUS I

MTL: 0.27 mm; MW:0.15 mm (0.15-0.17 mm); MFS: 0.27 mm.

Viewed laterally, the anterior part is elliptical due to the development of labrum. Viewed dorsally, the body is pear-shaped, the anterior part being wider, a median ocellus present near the anterior end ventrally; a dorsomedian spine present posteriorly; furcal seta 1+1 (Fig.1,j) which are approximately 1/4 to 1/5 as long as the body; 3 pairs of appendages present; A1 uniramous, 3 short lateral setae on inner margin, 1 short and 2 long setae terminally and 1 long seta on outer distal margin; A2 biramous, exopod slightly longer than endopod, endopod with 2 short lateral and 1 short and 2 long terminal setae, exopod with 5 long setae along inner lateral and terminal margin; Md biramous, each ramus with 3 long setae distally; all setae non-plumose. Duration of this substage was 5 hours.

NAUPLIUS II

MTL: 0.26 mm (0.25-0.27mm); MW: 0.155 mm; MFS: 0.07 mm (0.07-0.08mm).

Furcal setae 1+1 (Fig.1,k); no dorsomedian spine near the posterior end of body; A1 with 3 inner lateral setae; 3 terminal setae of which middle one is longest, and 1 outer lateral seta; endopod of A2 with 2 small inner lateral and 2 long terminal setae; exopod with 5 long setae and a small spike-like seta; distal region of the 4th seta bifurcate; the bifurcate condition is retained in other nauplius substages also; all setae plumose. Duration of this substage was 4½ hours.

NAUPLIUS III

MTL: 0.29 mm (0.28-0.29 mm); MW: 0.15 mm MFS: 0.11 mm (0.09-0.11 mm).

Caudal end of the body divided into 2 furcal processes each with 3 setae (Fig.2,a); endopod of A2 with 2 inner lateral and 3 distal setae, exopod with 6 setae and one spike-like seta. Duration of this substage was 7½ hours

NAUPLIUS IV

MTL: 0.31 mm (0.29-0.32mm); MW: 0.17 mm. (0.15-0.17 mm); MFS: 0.13 mm (0.13-0.14mm).

Developing frontal organ seen on either side of eye ; furcal setae 4+4; developing buds of mouth parts seen; Md (Fig.2,b) with a swelling at base. Duration of this substage was 3 hours.

NAUPLIUS V

MTL: 0.33 mm (0.32-0.34 mm); MW: 0.16 mm (0.15 mm-0.17 mm); MFS: 0.16 mm (0.15-0.17 mm).

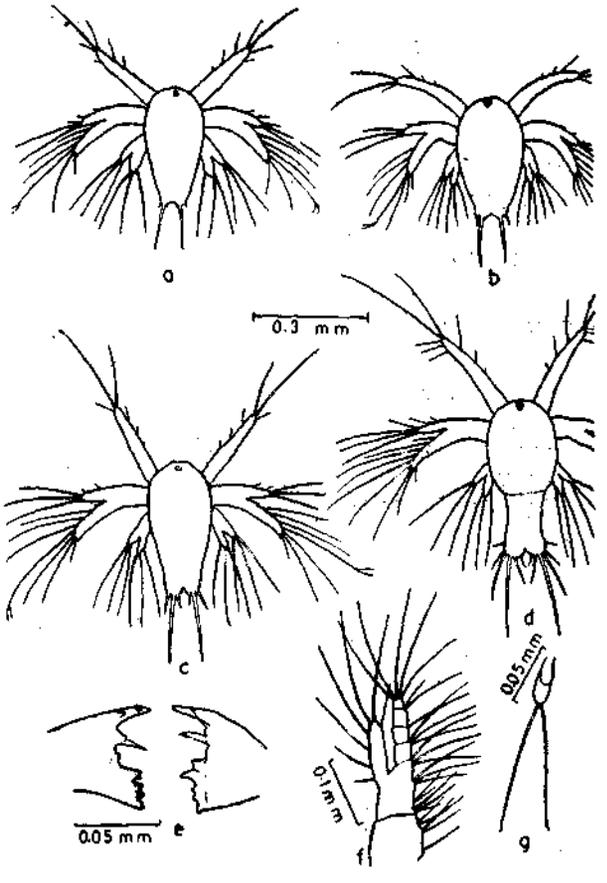

Fig: 2 *Metapenaeus brevicornis:* e - Nauplius III; b - Nauplius IV: c - Nauplius V; d - Nauplius VI. Protozoea I: e - Md; f - Mxp1; g - Mxp3.

Posterior region of larvae further elongated and furcal lobes more distinct bearing 6+6 setae (Fig.2,c); exopod of A2 with 7 long setae and 2 small spike-like setae, basal swelling of Md further developed. Duration of this substage was 4 hours.

NAUPLIUS VI

MTL: 0.39 mm (0.36-0.39 mm); MW: 0.16mm (0.15-0.18 mm); MFS: 0.22 mm (0.21-0.22mm).

Developing carapace clearly seen, developing frontal organ seen on either side of naupliar eye; furcal setae 7+7 (Fig.2, d), indistinct segmentation seen on proximal part of A1 and exopod of A2; A1 with 3 setae on inner margin, 3 setae apically and 3 setae on the distal outer margin; A2 endopod with 3 long and 1 short apical setae, and 2+1 inner lateral setae, exopod with 9 setae along inner and distal margin; protopod of Md with swelling which clearly shows developing Md tooth inside; buds of Mx and Mxp clearly developed. Duration of this substage was 20 hours.

PROTOZOEA I

MTL: 0.86mm (0.81-0.89 mm); MCL: 0.37mm (0.36-0.39 mm).

A1 (Fig. 3, b) uniramous, 3 segmented, proximal segment with 5 indistinct subsegments, basal segment with 1 short distal inner seta, middle segment with 3 distal setae of which one long, a small inner seta present at middle of this segment, distal segment bears terminally 2 long setae and 2 aesthaetes, a small seta present at distal outer aspect of this segment; A2 (Fig. 3, c) exopod 10 segmented carrying 10 setae along inner and distal margin, 2 short setae present on outer margin, endopod 2 segmented, distal segment with 4 long plumose and 1 short nonplumose setae apically, basal segment with 3 setae at distal inner margin, 2 in middle and 1 at base; Md (Fig. 2,d) almost symmetrical, incisor with 2-3 stout teeth, molar with a number of ridges, in between the 2 processes one free standing tooth present; Mx1 (Fig. 3, d) protopod with 2 endites, distal with 7 and proximal with 4 stout setae, exopod knob-like with 4 feathery setae, endopod 3 segmented, distal segment with 5 setae, 1st and 2nd segments bear 3 and 2 setae respectively; Mx2 (Fig. 3, e) protopod flat, with 5 endites on inner side, proximal endite carrying 6 setae, other endites with 3 to 4 setae, exopod knob-like carrying 5 feathery setae, endopod 4 segmented, segmentation between 2nd and 3rd segments indistinct, distal segment with 3 setae, other segments with 2 setae each; Mxp1 (Fig. 2, f) protopod 2 segmented, proximal with 5 and distal with 11-12 setae, exopod unsegmented carrying 7 plumose setae, endopod 4 segmented, 1st, 2nd, 3rd and 4th segments carrying 3, 1, 2 and 5 setae respectively; Mxp2 (Fig. 3, f) protopod indistinctly divided into 2, exopod unsegmented with 6 plumose setae, endopod 4 segmented, 1st, 2nd, 3rd, and 4th segments carrying 2, 1, 2 and 5 setae respectively; Mxp3 (Fig. 2, g) biramous bud, exopod carrying 2 setae apically, endopod bare; telson with 7 setae on each lobe. Duration of this substage was 48 hours.

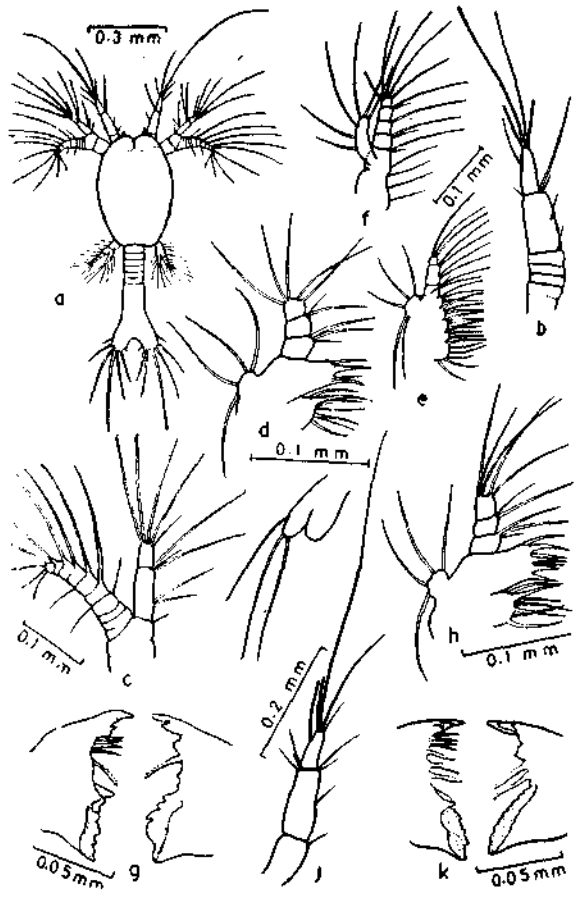

Fig. 3 *Metapenaeus brevicornis:* Protozoea I: a - dorsal view; b - A1; c - A2; d - Mx1; e - Mx2; f - Mxp2. Protozoea II: g - Md: h - Mx1; i - Mxp3. Protozoea III: j - A1; k - Md.

PROTOZOEA II

MCL: 0.50 mm (0.49-0.52 mm); MTL 1.14 mm (1.09-1.15 mm).

Eyes stalked, carapace with rostrum, supraorbital present (Fig.4,a), abdomen 6 segmented, telson not demarcated from last abdominal segment, carrying 7+7 setae; A1 distal segment carrying 1 aesthaetes and 4 setae of which one is long; Md (Fig. 3, g) asymmetrical, left with 5 and right with 1 free standing teeth in between

incisor and molar processes; Mx1 (Fig. 3, h) proximal and distal endites of protopod each with 7 setae; Mxp3 (Fig.3,i) exopod with 3 setae terminally. Duration of this substage was 40 hours.

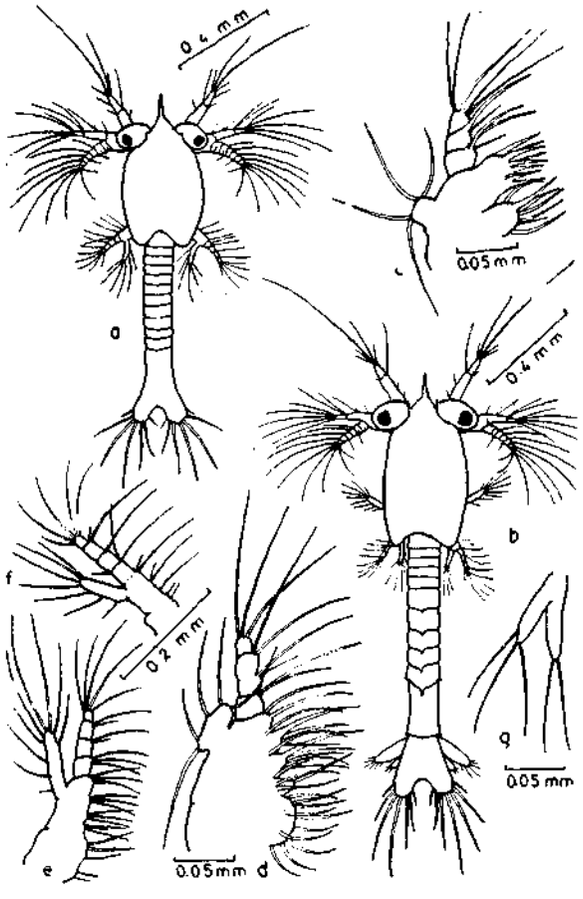

Fig. 4 *Metapenaeus brevicornis:* Protozoea II: a - dorsal view. Protozoea III: b - dorsal view; c - Mx1; d - Mx2; e - Mxp1; f - Mxp2; g- Mxp3.

PROTOZOEA III

MCL: 0.57 mm (0.56-0.58 mm); MTL: 1.46 mm (1.38-1.51 mm).

Rostrum prominent, supraorbital spine present, biramous buds of pereopods developed; 1st to 5th abdominal segments with dorsomedian spines, 5th segment with posterolateral spines; (Fig.4 b) telson demarcated from last abdominal segment by an articulating joint, each caudal lobe with 7+7 setae, uropod developed, exopod with 6 short setae apically and endopod with 3 short apical setae.

A1 (Fig. 3, j) 3 segmented, subsegments of basal segment absent, number of small setae on middle segment increased; Md (Fig.3,k) right and left Md with 2 and 7 standing teeth in between incisor and molar processes; Mx1 (Fig. 4, c) distal endite of protopod with 9 setae; Mxp1 (Fig.4, e) exopod with 9 setae Mxp 2 (Fig. 4, f) exopod with 7 setae; distal outer margin of 1st segment of endopod with 1 seta; Mxp3 (Fig. 4, g) exopod and endopod buds with 3 and 2 terminal setae respectively. Duration of this substage was 32 hours.

MYSIS I

MCL: 0.69 mm (0.67-0.70 mm); MTL: 1.97mm (1.96-1.99 mm).

. Carapace with rostrum just falling short of anterior end of eye (Fig.5,a), rostrum devoid of teeth, antennal and pterygostomial spines

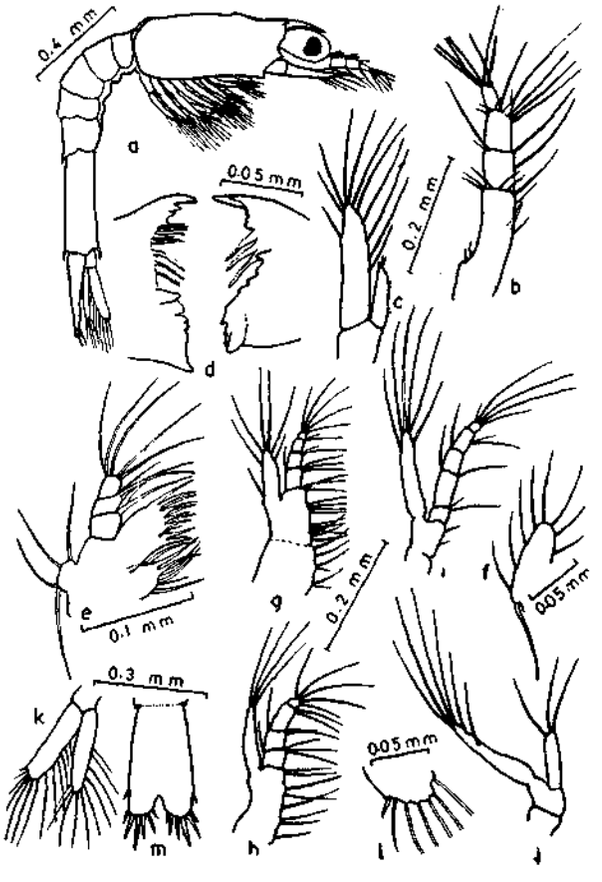

Fig. 5 *Metapenaeus brevicornis:* Mysis I: a - lateral view; b - A1; c - A2; d Md; e - Mx1; f - exopod of Mx2; g - Mxp1; h - Mxp2; i - Mxp3; j - P1; k - uropod. l: distolateral margin of exopod of uropod; m: telson.

well developed, small but distinct supraorbital spines present, 5th and 6th abdominal segments with dorsal spines, no lateral spine on 5th and 6th abdominal segments, a prominent ventro-median spine on posterior end of 6th abdominal segment at junction with telson, no pleopod bud on abdomen, telson with 7+ 7 setae, deep cleft reaching level of origin of outermost pair of setae.

A1 (Fig. 5, b) 3 segmented, basal segment with prominent ventral spine, slight basal swelling with 2 setae just above stylocerite rudiment, outer flagellum with 6 aesthaetes and 1 seta, inner flagellum short bearing 1 short and 1 long seta apically; A2 (Fig. 5, c) exopod and endopod unsegmented, exopod scale-like bearing 10 setae along inner and distal margin and 1 seta at distolateral angle, endopod half length of exopod, bearing short setae apically and on inner side; Md (Fig.5, d) left Md with 8 and right with 3 free standing teeth; Mx1 (Fig.5,e) distal endite of protopod with 11 setae; Mx2 exopod with 9 plumose seta (Fig.5,f); Mxp1 (Fig.5,g) exopod with 7 plumose setae, below the proximal outer lateral seta a few small hair-like setae seen, 1 outer lateral seta added to 1st segment of endopod; Mxp2 (Fig.5,h), 1st and 2nd segments of endopod acquired 1 distal outer seta each; Mxp3 (Fig.5,i) fully developed 5 segmented endopod, distal segment with 5 seta, 1st, 2nd and 4th segments carrying 2, 1 and 2 setae respectively, along the distal inner margin, 2nd and 3rd segments each carrying one seta on distal outer margin; P1 to P5 almost identical (Fig.5,j) exopod and endopod not segmented, exopod with 4 apical and 2 pairs of subapical plumose setae, endopod shorter than exopod bearing 3 apical setae; exopod of uropod (Fig.5,k) with 12 plumose setae and 1 nonplumose seta, endopod with 10 plumose seta.

REMARKS

This is the first time that the larvae of *M. brevicornis* are described. The pattern of development and the setation of appendages is closely similar to that of the other species of the genus *Metapenaeus* as described by Thomas *et. al.*, (1975, *ndian J, Fish.*, 21 (2): 575-579) Raje and Ranade (1975, *J. Indian Fish Ass.*, 2 (2): 30.46[2]). Intermoult lengthening of the thoracic and abdominal segments was observed in protozoea I and II. The newly hatched protozoea I moasured 0.69-0.73 mm in total length whereas it was 0.81-0.89 mm just before they moult into protozoea II. There was no change, however, in the carapace length. The presence of a distinct though small, supraorbital spine in mysis I appears to be characteristic of *M. brevicornis*.

IX

Larval development — *PARAPENAEOPSIS STYLIFERA* (H. MILNE EDWARDS)

M. S. Muthu
N. N. Pillai
K. V. George

Parapenaeopsis stylifera was reared from the egg to the postlarval stage in the Narakkal laboratory. It passes through 6 nauplius substages, 3 protozoea substages, and 7 mysis substages before reching postlarva I. At the rearing temperature of 25.6°C to 27.7°C the nauplii hatch out from the egg 15 to 16 hours after spawning; the duration of the nauplius stage is 40 to 50 hours: the protozoea stage lasts for 4½ to 7 days, and the larvae remain in the mysis stage for 10 to 16 days before becoming postlarva I. The complete development from egg to postlarva I takes 17 to 26 days. All the larval substages are described and illustrated in detail and compared with the earlier larval descriptions of this species.

Parapenaeopsis stylifera which is an important component in the prawn catch of the southwest coast of India was successfully made to spawn in the Prawn Culture Laboratory at Narakkal on a number of occasions and the larvae reared to the juvenile stage While routinely checking the larval characters with the description given by Rao (1974, *J.mar. biol. Ass. India*, 15(1): 95-124[1]), who had traced the complete life cycle of *P. stylifera* from the material collected from the plankton, it was apparent that the larvae differed considerably from Rao's[1] description. Our studies based on larvae of known parentage, gave us an opportunity to present here an authentic description of the complete series of larval stages of *P. stylifera*. The temperature of the water in the rearing basins was 25.6°C to 27.7°C and the salinity 33.1 - 34.3 ppt. The authors are grateful to Dr.E.G. Silas, Director, Central Marine Fisheries Research Institute, for his constant encouragement and valuable suggestions.

DESCRIPTION OF DEVELOPMENTAL STAGES

EGGS

The eggs (Fig.,1a,b,c) opaque with fairly wide perivitelline space, chorion with bluish sheen, egg diameter varied from 0.35 to 0.38 mm and yolk mass 0.22 to 0.27 mm. Embryonic development takes 15-16 hours.

NAUPLIUS I

MTL : 0.27 mm (0.26 - 0.28 mm); MW: 0.15mm (0.14-0.15 mm) MFS: 0.08 mm (0.07-0.08 mm)

Furcal setae 1+1; A1 with 3 short lateral setae on inner margin, 1 long lateral seta on outer margin and 2 long setae and 1 minute setal rudiment terminally (Fig.1,d); A2 exopod with 5 long setae, endopod with 2 long terminal and 2 short inner lateral setae; Md with 3 setae on both exopod and endopod; setae nonplumose. Duration of this substage was 3-4 hours.

NAUPLIUS II

MTL: 0.27 mm (0.26-0.28 mm); MW: 0.15mm (0.14-0.15 mm); MFS: 0.10mm (0.08-0.11mm).

Furcal setae 1+1; outer lateral and outer terminal setae of A1 short, setal rudiment of

nauplius I grown into a short seta (Fig.1,e); minute setal rudiment added to exopod and endopod of A2, 4th exopod seta counting

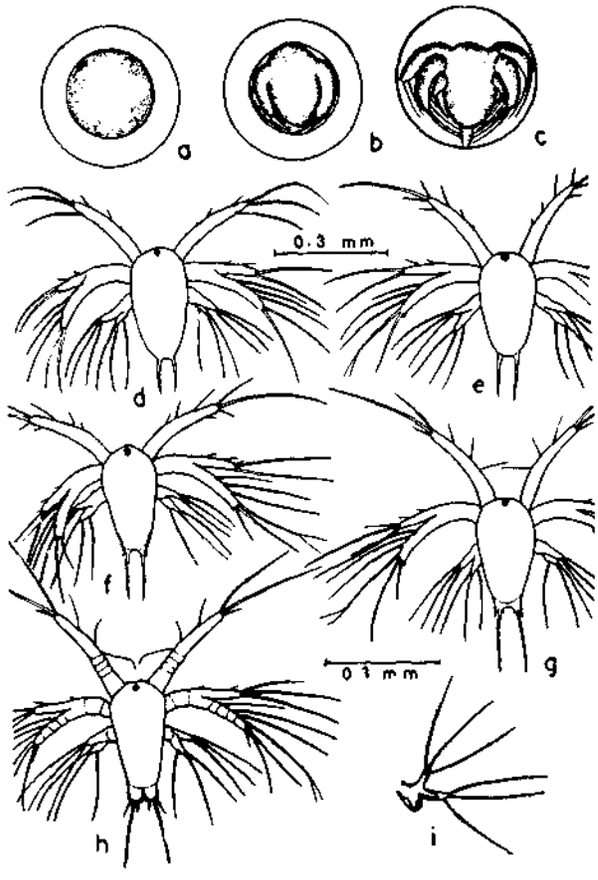

Fig. 1 *Parapenaeopsis stylifera:* a, b and c - egg in different stages of development: d - Nauplius I; e - Nauplius II; f - Nauplius III; g - Nauplius IV; h - Nauplius V: i - Md of nauplius VI.

from proximal end is bifurcate, this bifurcate condition retained in all subsequent nauplius substages; setae plumose. Duration of this substage was 3-4 hours.

NAUPLIUS III

MTL; 0.27 mm (0.26-0.29 mm);MW: 0.15 mm (0.14 - 0.15 mm);MFS:0.13 mm (0.11-0.14 mm).

Furcal setae 3+3; outer terminal seta of A1 smaller and inner terminal seta longer than in nauplius II (Fig. 1,f), outer lateral seta usually absent, if present hair-like and very thin, the 3 inner lateral setae longer; exopod of A2 with 6 plumose setae and a setal rudiment. Duration of this substage was 4-6 hours.

NAUPLIUS IV

MTL : 0.30 mm (0.28 - 0.31 mm); MW: 0.15 mm (0.14 - 0.15 mm); MFS: 0.16 mm (0.14 - 0.17 mm).

Furcal setae 4+4 (Fig.1, g),inner terminal seta of A1 longer, of the 3 inner lateral setae, the most proximal one is thin and very long; terminal setal rudiment of A2 endopod of previous stage grown into medium nonplumose seta; buds of mouth parts visible through cuticle. Duration of this substage was 3 - 4 hours.

NAUPLIUS V

MTL: 0.31 mm (0.29-0.32 mm); MW: 0.15 mm (0.14-0.15 mm); MFS: 0.19mm (0.18 0.20mm).

Furcal setae 6+6 (Fig.1,h), A1 faintly segmented basally, proximal inner lateral seta very long, bent and directed posteriorly and often seen overlapping its fellow on opposite side; A2 exopod with 6 plumose setae and 1 nonplumose seta, endopod with 3 long plumose setae apically, 5 indistinct segments on exopod; Md has a prominent swelling near base. Duration of this substage was 10-12 hours.

NAUPLIUS VI

MTL: 0.37 mm (0.35-0.39 mm) MW: 0.15 mm (0.14-0.16 mm) MFS: 0.22 mm (0.21-0.23mm).

Furcal setae 7+7; (Fig.2,a,) the pair of setae immediately inner to longest pair, bent ventrally and outwardly; carapace demarcated, frontal organs prominent; A1 with 4 basal segments, a short outer terminal seta added next to existing one, 1 short seta and 1 minute seta added on outer distal margin; A2 exopod 7 segmented, exopod with 7 plumose setae and 2 setal rudiments, 1 proximal and 1 terminal, endopod with 3 long plumose setae and 1 short non-plumose seta apically, distal of 2 inner lateral setae longer; swelling at base of Md (Fig.1,i) very prominent with cutting blades visible inside. Duration of this substage was 17 to 20 hours.

PROTOZOEA I

MTL: 0.64 mm (0.61-0.66 mm); MCL: 0.27 mm (0.25-0.28 mm).

Frontal organs rounded (Fig.2,b); A1 longer than A2; telson deeply forked, with 7+7 setae,

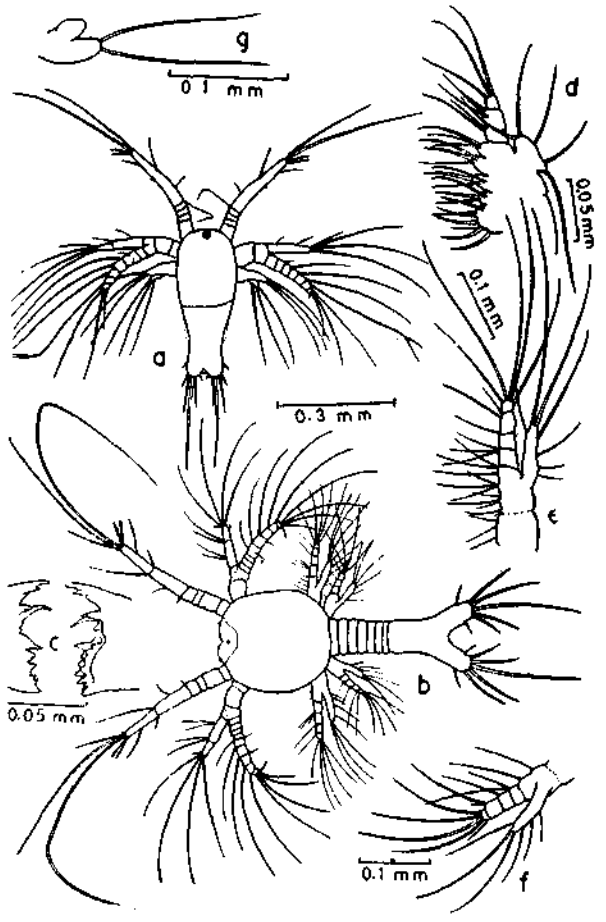

Fig. 2 *Parapenaeopsis stylifera*, a - Nauplius VI; Protozoea I: b - dorsal view; c - Md; d - Mx2; e - Mxpl; f - Mxp2; g - Mxp3.

each caudal furca relatively long and narrow, outermost pair of lateral setae separated from penultimate pair by a wide gap.

A1 (Fig.2,b) 3 segmented, basal segment with 4 subsegments, 3 inner lateral setae on middle segment, characteristic long proximal seta of nauplius VI reduced in size, distal one longest, terminally 2 very long setae, 1 medium seta, 2 short aesthaetes and 1 minute setal rudiment, 2 setae present on outer lateral aspect; A2(Fig.2,b) exopod 10 segmented with 10 setae along inner and distal margin, 2 smaller lateral setae on outer margin, endopod 2 segmented with 2+2 lateral setae and 4 long setae and a short hair apically; Md (Fig,2,c) more or less symmetrical with 1 standing tooth between incisor and molar processes; Mx1 (Fig.3,a) protopod with 2 endites, distal one with 4 setae and proximal with 6 to 7 setae, endopod short and 2 segmented, distal segment with 4 terminal setae and 1 inner lateral seta, proximal segment with 3 inner lateral setae, exopod button-like with 4 feathery setae; Mx2 (Fig.2,d) protopod with 5 endites, large proximal one with 7 setae and rest with 3 setae each, endopod short

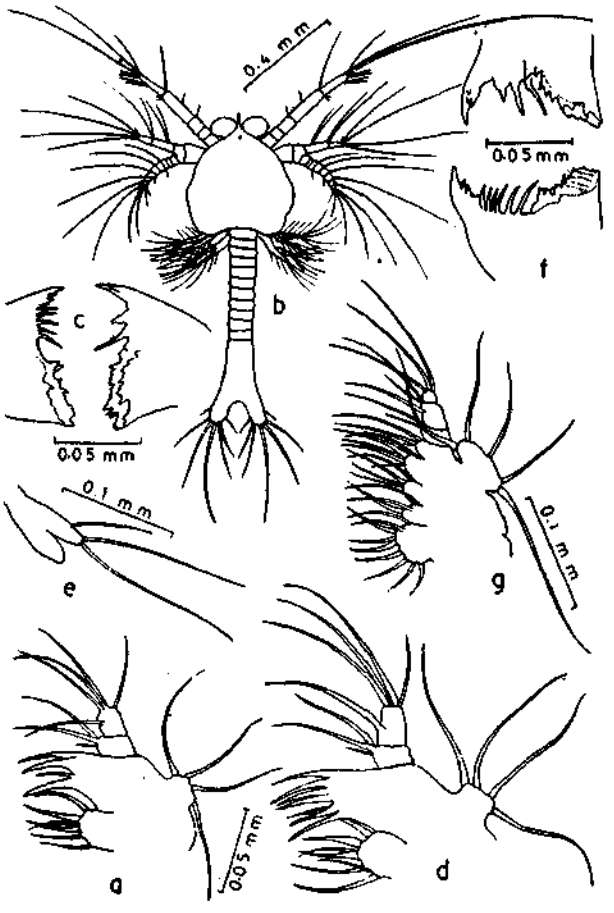

Fig. 3 *Parapenaeopsis stylifera:* Protozoea I : a - Mxl. Protozoea II: b - dorsal view; c - Md; d - Mxl e - Mxp3; Protozoea III: f - Md; g - Mx2.

with 3 segments, distal segment with 3 long terminal setae, middle one with 2 distolateral and one lateral seta in middle and basal segment with 2 distolateral setae, exopod with 5 feathery setae; Mxp1 (Fig.2,e) protopod indistinctly 2 segmented, distal segment bearing 11 to 12 inner lateral setae and proximal one with 3 inner lateral setae, endopod 4 segmented, 1st segment with 3, 2nd with 1, 3rd with 2, and 4th with 5 setae, exopod shorter than endopod, with 7 setae, terminal setae on exopod and endopod very long, more than twice length of exopod and endopod; Mxp2 (Fig.2,f) protopod faintly 2 segmented with fewer number of setae, endopod 4 segmented with 2 setae on 1st segment, 1 on 2nd, 2 on 3rd and 5 setae

on distal segment, exopod unsegmented with 6 setae; Mxp3 (Fig.2,g) biramous bud with 2 setae on exopod. Duration of this substage was 24-48 hours.

PROTOZOEA II

MTL: 1.12 mm (1.08-1.18)mm; MCL:

Short rostrum, no supraorbital spines, eyes stalked (Fig.3,b); intermoult lengthening of abdominal segments noticed, buds of thoracic appendages developed during intermoult growth and developing uropods could be seen inside cuticle.

A1 (Fig.3,b), one more seta added to distal seta on outer lateral aspect and 1 to 2 hair-like setae added at junction of distal and middle segments, basal segment with 3 subsegments; Md (Fig.3,c) asymmetrical, right Md with single free standing tooth between incisor and molar processes and left with 5 free standing teeth, a blunt tooth present just above standing tooth on right Md; Mx1 (Fig. 3,d) distal and proximal endites with 7 setae. each; Mx2, basal endite with 9 setae and the rest with 3 to 4 setae, no change in exopod or endopod; 2 more setae added to basal segment of protopod of Mxp1; Mxp3 (Fig.3,e) exopod with 3 setae. Duration of this substage was 56-72 hours.

PROTOZOEA III

MTL: 1.55 mm (1.51 - 1.64 mm ; MCL: 0.51 mm (0.50 - 0.53 mm).

No change in carapace; abdominal segments 1 to 5 (Fig.4,a) with dorsomedian spines, 5th segment with a pair of lateral spines, 6th abdominal segment without dorsal spine, but with a pair of posteroventral spines; telson with 8+8 setae; uropods developed, exopods tipped with 6 small setae (Fig.4,a) ; biramous rudiments of thoracic legs present.

A1 (Fig.4,a) clearly 4 segmented, 3 subsegments of basal segment fused into one, setation not changed from previous stage, except for a few more hair like setae added to junction of distal segment with penultimate segment; Md (Fig.3,f) 2 standing teeth in right Md and 6 in left; Mx1 with 8 setae on distal endite; Mx2 (Fig.3,g) basal endite with 9 setae and the rest with 3 to 5 setae; Mxp1 (Fig.4,b) exopod with 9 setae, no other

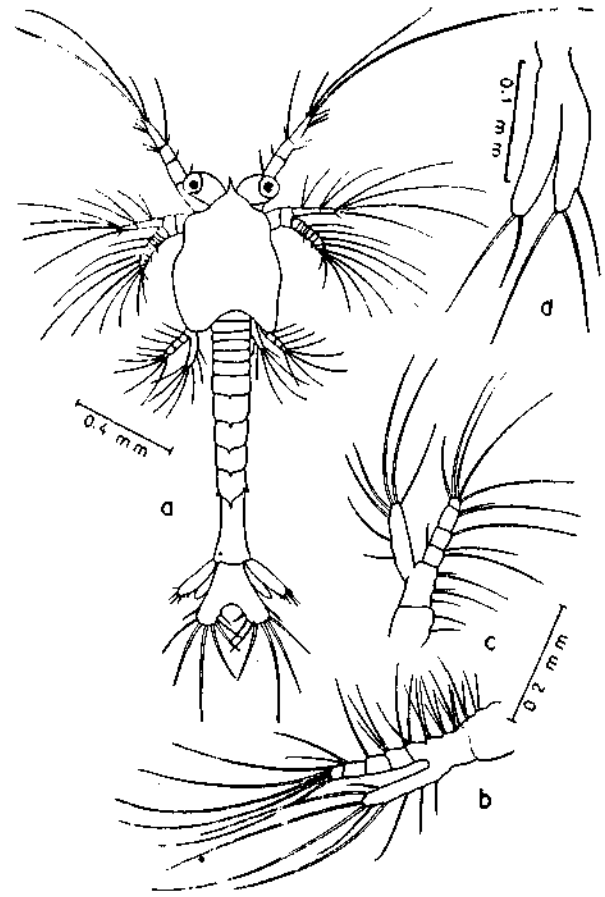

Fig 4. *parapenaeopsis stylifera*: Protozoea III; a - dorsal view; b - Mxp 1; c - Mxp2; d - Mxp3.

change, Mxp2 (Fig.4,c) exopod with 7 setae; a short outer lateral seta added to basal segment of endopod; Mxp3 (Fig.4,d) exopod bud with 3 setae and endopod bud with 2setae. Duration of this substage was 24-48 hours.

MYSIS I

MTL: 2.00 mm (1.8- 2.1 mm); MCL: 0.64 mm (0.58 - 0.66 mm) .

Carapace with rostrum shorter than eye (Fig.5,a), a minute supraorbital spine, a prominent pterygostomial spine and a smaller antennal spine present; dorsal organ prominent in lateral view; dorsomedian spine present only on 5th and 6th abdominal segments; a vestige of lateral spine on 5th abdominal segment still present; a ventral posteromedian curved spine present on 6th segment; telson with 8 pairs of setae (Fig.5,k); cleft on telson extending to level of origin of outermost pair of lateral setae.

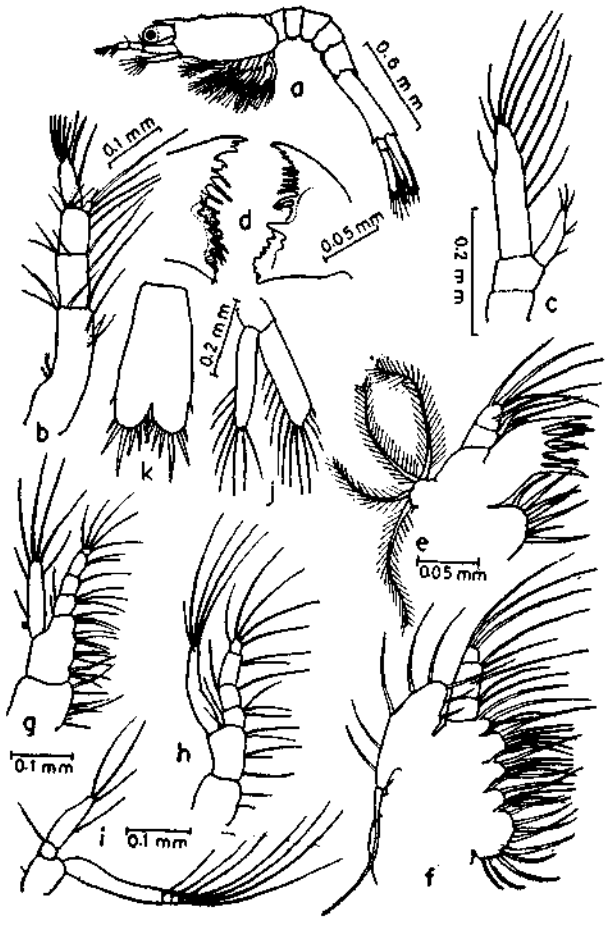

Fig. 5. *Parapenaeopsis stylifera:* Mysis I: a - lateral view; b - A1; c - A2; d - Md; e - Mx1; f - Mx2, g - Mxp1; h - Mxp2; i - P1; j - uropod: k - telson;

A1 (Fig.5,b) 3 segmented, distal segment carries 2 flagellar rudiments, larger one tipped with 6 aesthaetes and 1 small seta and smaller bud-like one tipped with 2 setae, 1 long and 1 short, the 1st segment has a basal swelling wherein statocyst is developed in later substages , 2 short setae present above this swelling distally, on the ventromedian aspect a prominent spine present; A2 (Fig.5,c) scaphocerite with 10 setae on inner and distal margin and 1 disto-lateral seta, endopod very short with 3 terminal setae and 2+1 lateral setae; Md (Fig.5,d) 3 free standing teeth in right Md and 7 in left; Mx1 (Fig.5,e) exopod with 4 feathery setae still present, distal endite with 9 setae; Mx2 (Fig.5,f) exopod larger with 9 feathery setae, basal endite with 10 setae, distal endite with 3 and 3 middle endites with 5 to 7 setae; Mxp1 (Fig.5,g) protopod broader, exopod with 7 long setae and a few hair-like setae below the proximal outer setae, 1 outer lateral seta added to 1st segment of endopod, 1 outer seta at junction with protopod, terminal setae of endopod shorter than length of endopod; Mxp2 (Fig.5,h) exopod with 6 setae, 4 terminal and 2 subterminal, endopod still 4 segmented with outer lateral setae on 1st and 2nd segments and also at junction with exopod, 1 more inner seta added to basal segment of endopod. Mxp3 (Fig.6,a) well developed, endopod 5 segmented distal segment with 5 setae, 4th segment with 1 outer and 1 inner lateral setae, 3rd segment without any seta, 2nd with 1 outer and 1 inner seta and the 1st with one inner lateral seta; exopod as long as endopod, with 4 long terminal setae and 2 pairs of subterminal setae, 2 indistinct segmentations seen at distal end; endopod of P1 to P3 (Fig. 5, i) 2 segmented without rudiments of chela, distal segment with 3 terminal setae and 1 long outer lateral seta in middle of segment and 1 inner lateral seta on basal segment, exopods with 4 terminal and 3 pairs of subterminal setae, tip of exopod indistinctly 3 segmented; endopod of P4 to P5 unsegmented with 3 terminal setae, exopods with 4 terminal and 3 pairs of subterminal setae; exopod of uropod (Fig. 5, j) with 12 plumose setae and one short nonplumose seta at outer lateral corner, endopod with 8 setae. Duration of this substage was 24-36 hours.

MYSIS II

MTL: 2.25 mm (2.21-2.28 mm); MCL: 0.69 mm (0.67-0.71 mm).

Carapace without prominent dorsal organ, minute supraorbital still present, no hepatic spine, no pleopod buds on abdominal segments (Fig. 6, b); vestiges of the pair of lateral spines on 5th abdominal segment lost; telson with cleft extending only up to level of origin of penultimate pair of lateral setae (Fig. 6, i).

A1 with 3 setae above statocyst swelling; A2 (Fig. 6,c) with 14 setae on scaphocerite, distolateral seta replaced by a prominent spine, endopod small with a short basal segment; Md (Fig.6,d) small palp seen; Mx1 (Fig.6,e) exopod, lost; Mx2 exopod with 13 setae; Mxp1 terminal setae on endopod slightly shorter than endopod, 1 outer lateral seta added to 2nd segment; Mxp2 endopod 5 segmented, penultimate segment of mysis I divided into 2; Mxp3, 1 more seta added to inner margin of basal segment of endopod,

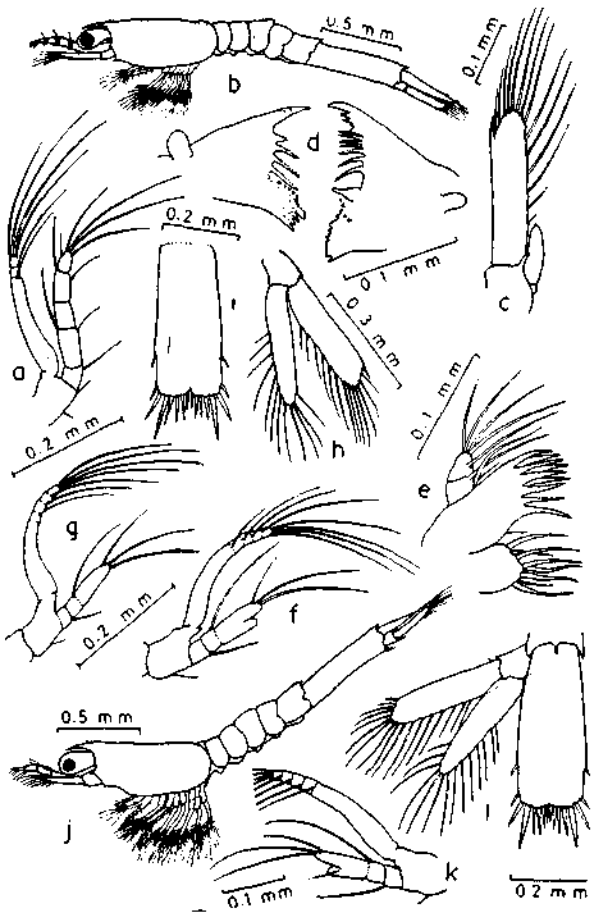

Fig. 6. *Parapenaeopsis stylifera:* Mysis I: a - Mxp3. Mysis II: b - lateral view; c - A2; d - Md; e - Mx1; f - P1; g - P5; h - uropod; i - telson. Mysis III: j - lateral view; k - P1; l - uropod and telson.

exopod with 4 terminal and 3 pairs of subterminal setae; P1 to P3 (Fig. 6, f) endopod with incipient chelae bearing 3 long setae terminally, with faint segmentation at level of origin of long outer seta, exopods with 4 pairs of subterminal setae arranged symmetrically below the 4 terminal setae, in some it may be 3 + 4 + 4, distally 4 indistinct segments seen; P4 and P5 identical, similar to P1 to P3 but without chela (Fig. 6,g); uropod (Fig. 6, h) exopod with 12 to 13 plumose setae and 1 nonplumose, short distolateral seta. outer margin of exopod not produced into a fixed spine, endopod with 11 to 12 setae. Duration of this substage was 24-48 hours.

MYSIS III

MTL: 2. 39 mm (2.28 - 2.41 mm); MCL: 0.75 mm (0.74 - 0.76mm).

A minute rostral tooth present (Fig. 6, j), supraorbital spine absent, no hepatic spine, still no pleopod buds, telson with shallow cleft (Fig. 6,l).

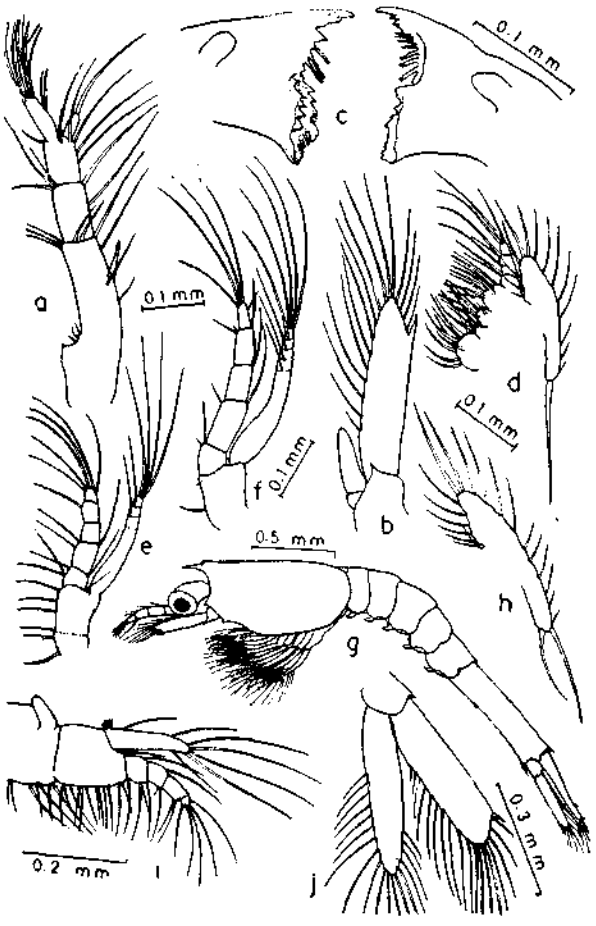

Fig. 7. *Parapenaeopsis stylifera:* Mysis III: a - A1; b - A2; c - Md; d - Mx2; e - Mxp2; f - Mxp3. Mysis IV; g - lateral view; h - exopod of Mx2; i - Mxp1; j - uropod.

A1 (Fig. 7,a) 2 subterminal aesthaetes added to outer flagellar rudiment; A2 (Fig 7,b) scaphocerite with 16 setae and a distolateral spine, endopod 1/3 length of scale; Md (Fig.7,c) palp larger; Mx1 distal endite with 10 setae, proximal endite with 8 setae; Mx2 (Fig. 7,d) exopod with 15 setae; Mxp1 a small gill rudiment present on outer distal corner of basal segment of protopod, 1 inner lateral seta added to 2nd segment of endopod; Mxp2, (Fig.7,e) one more inner lateral seta added to 2nd segment and another terminal seta to distal segment, 1 seta added to junction of exopod and endopod, exopod with 8 setae, 4 terminal and 2 pairs of subterminal; Mxp3 (Fig.7,f) exopod with 12 setae, 4 terminal and 4 pairs of subtermial, 1 outer lateral seta

added to 3rd segment of endopod; P1 to P3 (Fig.6,k) exopods with 12 setae (4+4+4),endopod with an additional seta in well formed cleft of chela; P4 and P5 with an additional short inner distolateral seta; uropod (Fig.6.l), exopod with 16 plumose setae and 1 nonplumose distolateral seta, endopod with 14 setae. Duration of this substage was 48-72 hours.

MYSIS IV

MTL: 3.19 mm (3.10-3.36 mm); MCL: 0.93 mm (0.91-1.05 mm).

Rostrum extending only up to ½ eye, rostral tooth well formed, no hepatic spine (Fig.7,g), cleft of telson very shallow, short pleopod buds appear (Fig.7,g).

A1 with 4 setae above stylocerite, 1 more terminal aesthaetes added to outer flagellar rudiment and 1 short seta to inner flagellar, rudiment; A2 (Fig.8,a) scaphocerite with 17 setae and one distolateral spine, endopod nearly ½ length of scale, Md (Fig.8,b) palp prominent; Mx2 exopod with 20 setae (Fig.7,h), one outer seta added to basal segment of endopod; Mxp1 (Fig.7,i) gill rudiment more prominent, tuft of hair-like setae on outer proximal margin prominent; Mxp2 with one outer lateral seta added to 3rd segment of endopod, exopod with 2+4+2 setae: P1 to P3 (Fig.8,c) with well formed chela, tips of chelae pointed, endopod 4 segmented, 2 additional setae originate from faint demarcation of dactylus from propodus, 1 short inner seta added to 3rd segment, exopod with 4+4+4 setae, appears to have 4 distal segments; P4 and P5 (Fig.8,d) with 5 segmented endopod, 2 additional setae at junction of dactylus with propodus; uropod (Fig.7,j) exopod with 17 to 18 plumose setae and 1 nonplumose distolateral seta; endopod with 17 to 18 setae. Duration of this substage was 48-72 hours.

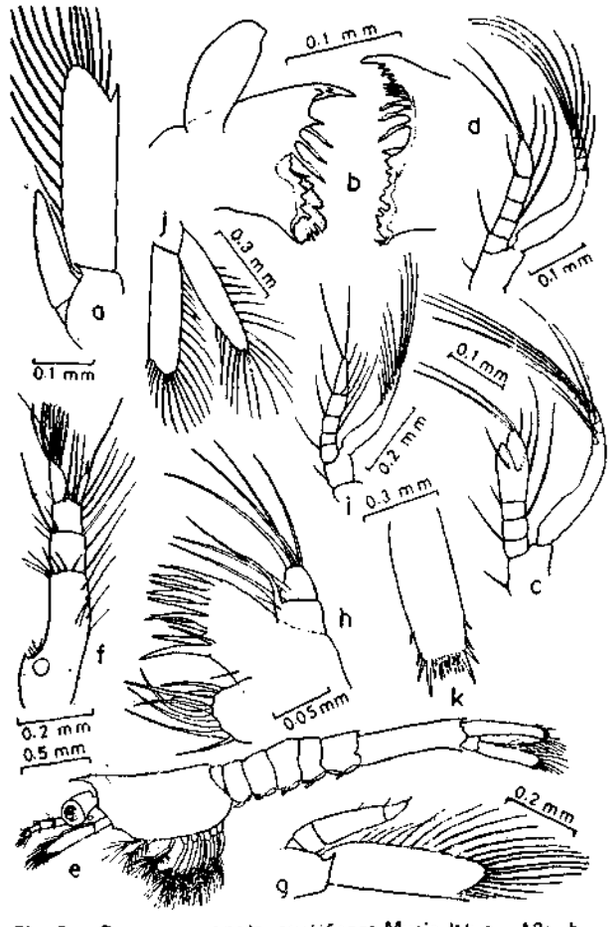

Fig. 8- *Parapenaeopsis stylifera*; Mysis IV: a - A2; b - Md; c-P1; d - P5. Mysis V: e - lateral view; f - A1; g - A2; h - Mx1; i - P5; j - uropod; k - telson.

MYSIS V

MTL: 3.49 mm (3.48 - 3.51 mm); MCL: 1.01 mm (1.01-1.02 mm).

Rostrum short, extending to ½ eye (Fig.8,e), single rostral tooth, pleopod rudiment longer, unsegmented, telson without cleft (Fig.8,k).

A1 (Fig.8,g) scaphocerite with 21 setae and 1 diatolateral spine, endopod 4 segmented, tipped with a seta, 2 minute lateral setae may be present; Md with large palp; Mx1 (Fig.8,h) with 11 setae on distal and 8 setae on proximal endites; Mx2 (Fig 9,a) exopod with 25 setae; Mxp1 with gill rudiment longer, exopod with more hair-like setae proximal to outermost seta; Mxp2 no change in endopod, exopod with 3+4+3 setae; Mxp3 (Fig.9,b) exopod with 5+4+5 setae, gill rudiment present on basal segment of protopod; exopod of P1 to P3 (Fig.9,c) with 6+4+6 setae; exopod of P4 and P5 (Fig.8,i) with 6+4+6 setae, some with 5+4+6 setae; uropod (Fig,8,j) exopod with 20 plumose setae and a nonplumose distolateral seta, endopod with 19 setae. Duration of this substage was 36-56 hours.

MYSIS VI

MTL: 3.85 mm (3.76 -3.93 mm); MCL: 1 12 mm.

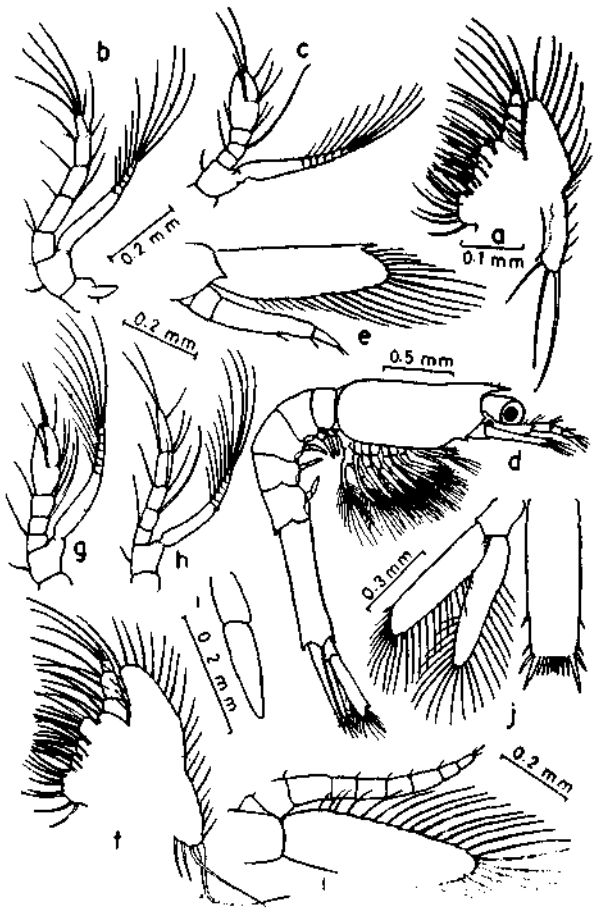

Fig. 9. *Parapenaeopsis stylifera*: Mysis:V: a - Mx2 b - Mxp3; c - P3. Mysis VI: d - lateral view; e - A2d f - Mx2; g - P3; h - P5; i - pleopod; j - uropod an; telson. Mysis VII: k - A2.

Rostrum (Fig.9,d) with 1 tooth, pleopods short but 2 segmented (Fig.9,i).

A2 (Fig.9,e) scaphocerite with 21 to 22 plumose setae and a distolateral spine, endopod ¾ of scale, 4 segmented, tipped with 2 setae, 2 lateral setae present; Md palp larger; Mx2 (Fig.9,f) exopod with 27 setae; Mxp2 exopod with 4+4+4 setae; P1 to P3 chelae longer (Fig.9,g) ; endopods of P4 and P5 longer than exopods (Fig.9,h) ; uropod(Fig.9,j) exopod with 21 to 23 plumose setae and a nonplumose distolateral seta; endopod with 21 to 22 setae. Duration of this substage was 36-56 hours.

MYSIS VII

MTL: 3.85 mm (3.68 - 4.09 mm); MCL: 1.13 mm (1.12 - 1.16 mm).

2 rostral teeth (Fig. 10, a) hepatic spine still absent, pleopods long and 2 segmented, but without setae (Fig. 10,h), telson slightly convex.

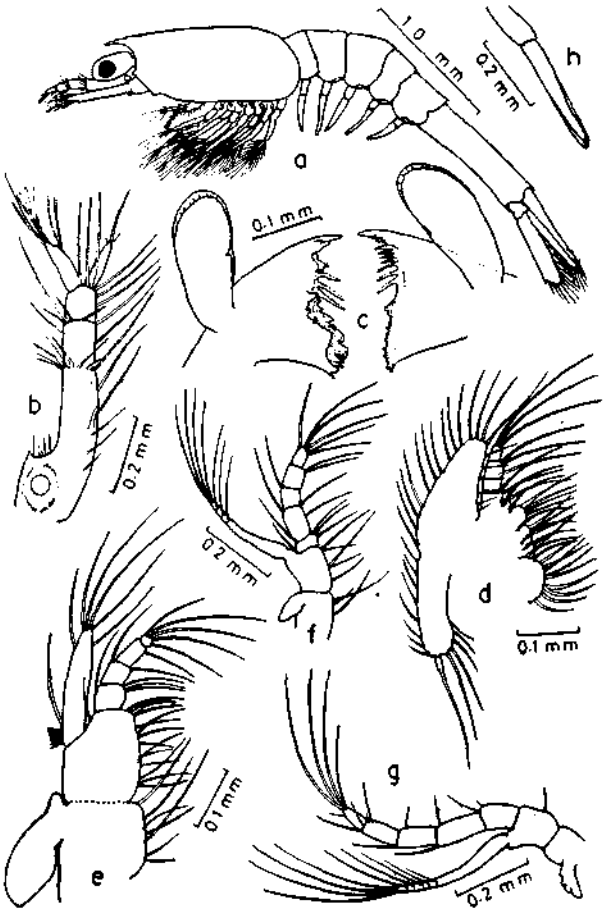

Fig. 10. *Parapenaeopsis stylifera*: Mysis VII: a - lateral view; b A1; c - Md; d - Mx2; e - Mxp1; f - Mxp2; g - Mxp3; h - pleopod.

A1 (Fig. 10,b) with 5 setae above stylocerite, inner flagellum almost as long as outer; A2 (Fig. 9,k) scaphocerite with 24 setae and a distolateral spine, endopod longer than scaphocerite and 8 segmented with 5 lateral and 3 terminal setae; Md (Fig. 10,c) with palp large and club; shaped; Mx2 (Fig. 10,d) exopod with 33 setae Mxp1 (Fig. 10,e), gill larger, number of hair-like setae on exopod increased; Mxp2 (Fig. 10,f), gill rudiment prominent; Mxp3 (Fig. 10,g) exopod with 6 + 4 + 6 setae, gill rudiments prominent; P1 to P5 endopods longer than exopods, dactylus clearly demarcated from propodus in the chelate legs, dactylus of P4 and P 5 pointed, bearing 2 setae and a minute spine; exopod of uropod with 22 plumose setae and a distolateral nonplumose seta, endopod with 21 setae. Duration of this substage was 24-48 hours.

POSTLARVA I

MTL: 3. 80 mm (3. 72- 3. 86 mm); MCL: 1.18 mm (1.13- 1.20 mm).

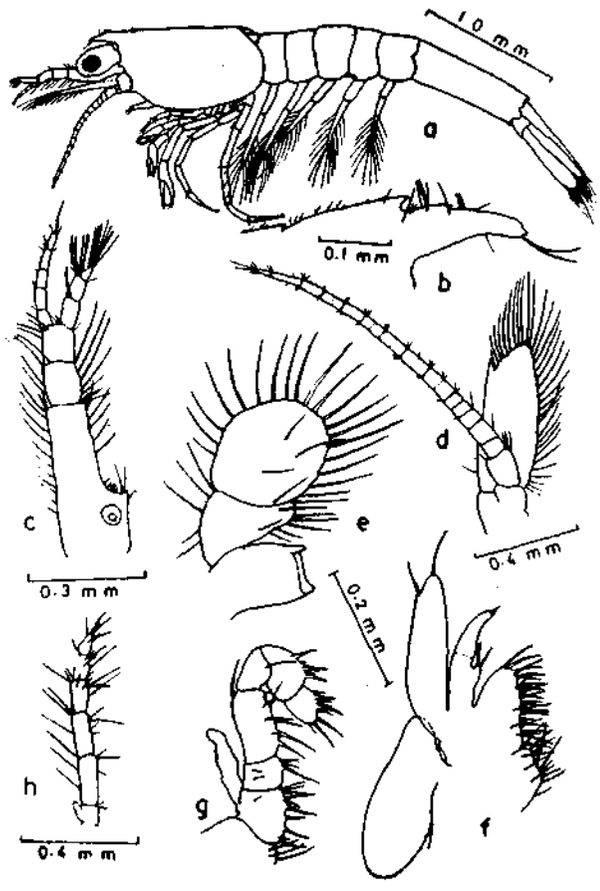

Fig. 11. *Parapenaeopsis stylifera*: Postlarva I: a - lateral view; b - tip of rostrum; c - A1; d - A2 e - Md; f-Mxp1; g - Mxp2; h - Mxp3.

Carapace with 2 rostral teeth and an epigastric tooth (Fig. 11,a), 2 long plumose setae originate subterminally on ventral side of rostrum, 2 short stout setae in front of 2 distal rostral teeth (Fig. 11,b), 3 spinules in between epigastric and penultimate rostral tooth and 1 minute spinule posterior to epigastric, hepatic spine present, dorsal spine on 5th abdominal segment has disappeared; posterior margin of telson tapering and ends in a prominent median spine which is longer than the 4 pairs of telsonic setae (Fig.12,j) present on either side of it; pleopods setose (Fig.12,g & h).

A1 (Fig.11,c) outer flagellum shorter than inner and 3 segmented, inner flagellum 5 segmented; A2 (Fig.11,d) scaphocerite broad with 33 plumose setae and a distolateral spine, flagellum longer than scale with 15 segments, some segments faintly subdivided into 2; Md (Fig.11,e) standing teeth absent but with sharp cutting edge between incisor and molar processes, palp well developed with 2 segments,

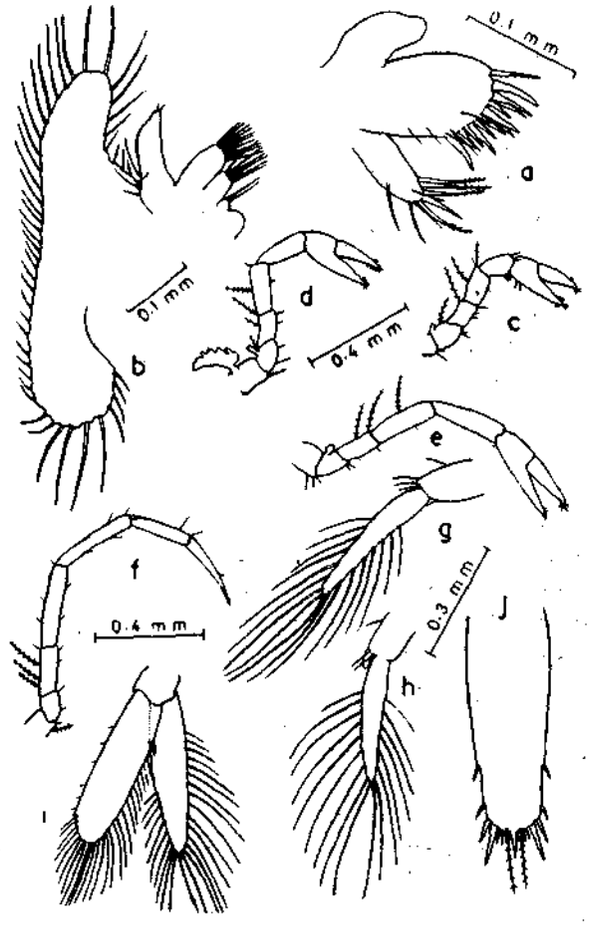

Fig. 12. *Parapenaeopsis stylifera*: Postlarva I; a-Mx1 b - Mx2; c - P1; d - P2; e - P3; f - P5; g - pleopod IV; h - pleopod V; i - uropod; j - telson.

distal oval one longer than proximal segment, numerous plumose setae on both segments; Mx1 (Fig.12,a), endopod reduced to unsegmented naked palp, more setae added to endites; Mx2 (Fig.12,b) exopod with 48 to 50 plumose setae, endopod reduced to unsegmented palp bearing 3 outer lateral setae and 2 minute terminal setae, 4 endites seen, distal bearing 10 setae, 3rd 6 to 7, 2nd 2 and 1st none; Mxp1 (Fig.11,f) protopod broad with more number of setae, endopod reduced to faintly

2 segmented palp with 3 short terminal setae and 2 small lateral setae, exopod with only 2 setae, 1 terminal and 1 subterminal, gill rudiment large; Mxp2 (Fig.11,g) endopod recurved, with stout bristles on distal and penultimate segments, exopod shrunken, without setae; Mxp3 (Fig.11,h) exopod vestigial and endopod with more nonplumose setae; P1 to P3 (Fig. 12,c,d,e) with functional chelae, without long terminal and lateral plumose setae, minute teeth present on inner distal margin of dactylus and propodus, exopod vestigial; endopod of P4 and P5 (Fig.12,f) with sharply pointed dactylus without long terminal plumose setae; distal segment of pleopods (Fig.12,g.h) with 17 to 19 long plumose setae, basal segment with 3 short distal setae and 1 short lateral seta; the 5th pleopod with small endopod bud (Fig.12,h); uropod (Fig.12,i) exopod with 27 to 29 Plumose setae and a distolateral tooth, endopod with 25 to 27 plumose setae.

DISCUSSION

Nauplius IV, V and VI of *Parapenaeopsis stylifera* possess a characteristically long proximal inner lateral seta on A1. This seta is so long that it overlaps its fellow from the other A1; it is directed posteriorly and invariably bent sharply in distal 1/3. Another interesting naupliar character of *P.stylifera* is the ventrally and outwardly bent disposition of the pair of furcal setae immediately medial to the longest pair of furcal setae in nauplius VI. The characteristic A1 setation and the peculiarly bent furcal setae are not seen in the nauplii of *P. stylifera* described and illustrated by Rao[1]. During the present study 6 nauplius substages were evident, whereas Rao[1] and Thomas et. al. (1974, *Indian J. Fish*), 21 (1) : 266-271) have described only 5.

During the present study it was found that the protozoea of *P. stylifera* are characterised by the following features: (1) the frontal organs are rounded in protozoea I; (2) A1 is distinctly longer than A2; (3) A2 endopod has 2 + 2 lateral setae and 4 long setae and 1 short hair terminally, in all the 3 protozoea substages; (4) the basal A1 segment has 4 subsegments in protozoea I and 3 subsegments in protozoea II; (5) the caudal furcae are narrow, long and widely separated from each other, in protozoea I and II; (6) supraorbital spines are absent in protozoea II and III; (7) A1 is clearly 4 segmented in protozoea III; (8) the endopod of Mx1 has only 2 segments, the distal segment bearing 4 terminal setae and 1 inner lateral seta whose origin appears to mark the position of the missing segment; (9) the endopod of Mx2 has only 3 segments, the single inner lateral seta on the middle segment appears to mark the position of the missing segment; (10) Mxp3 is rudimentary, represented by a setose biramous bud.

When compared with the present description the following discrepancies are noted in the illustrations of protozoea substages given by Rao[1]: (1) basal segment of the A1 has 5 subsegments in protozoea I and II (2) A^1 bears 3 subequal terminal setae in protozoea I, while in the present material one of them is considerably longer than the others; (3) proximal pair of lateral setae on the A2 endopod is shown as originating from the junction of the endopod with the protopod whereas they actually originate from the middle of the proximal endopod segment; (4) endopod of Mx2 is 5 segmented instead of being 3 segmented; (5) endopod of Mx1 is 3 segmented and not 2 segmented as observed in the present study; (6) A1 of protozoea III has only 3 segments, not 4; (7) Mxp3 of protozoea II and III are shown as fully developed biramous setose appendages with 4 segmented endopods, whereas they are actually very small biramous buds.

Based on the present study it can be said that the mysis stage of *P. stylifera* is characterised by the following features; (1) rostrum is short extending to about ½ length of eye; (2) hepatic spine is absent in all mysis substages; (3) small supraorbital spine present in mysis I and II; (4) left Md has 7 free standing teeth; (5) endopod of Mx1 2 segmented, the distal segment bears 4 terminal setae and 1 inner lateral seta in the middle; (6) endopod of Mx2 3 segmented, the middle segment has 2 distolateral setae and a single lateral seta in the middle of the segment; (7) exopod of Mxp1 with 7 plumose setae and a tuft of very thin hair-like setae on outer margin just below the outermost lateral seta; (8) telson bears 8 pairs of setae; (9) exopod of P1 to P5 with 10 plumose setae in mysis I, the number increasing to 16 in later mysis substages: (10) endopod

of P1 to P5 with a very long outer lateral plumose seta extending well beyond the tip of the endopod; (11) outer margin of the exopod of uropod is not produced into a short tooth or spine distolaterally; (2) there are at least 7 mysis substages.

Rao[1] in his account of the larval history of *P. stylifera* recognised only 3 mysis substages, has drawn hepatic spines for mysis II and III and has not shown the supraorbital spines even in mysis I. The absence of hepatic spine in all the mysis substages and the presence of supraorbital spine in mysis I and II were confirmed during the present study by examining hundreds of fresh specimens. Further, in the mysis substages of *P. stylifera* studied by us the setae on the exopod of Mx2 are distributed uniformly along the entire margin, but they are shown confined to the distal and proximal ends in the figures given by Rao, and the number of setae is also considerably lower than in the present material. The mysis substages attributed by George and Paulinose (1973, *I. O. B. C. Handbook*, v : 60-69) [3] to *P. stylifera* do not appear to belong to this species for the following reasons: (1) the rostrum extends well beyond the eye whereas in *P. stylifera* it clearly falls short of anterior end of eye; (2) the dorsal spine on 5th and 6th abdominal segments are very long. But the larvae described by them undoubtedly belong to some species of *Parapenaeopsis*.

The postlarva I does not differ much from the description of Mohamed et. al. (1969, *FAO Fish. Rep.*, 57 (2): 487-503). The broad A2 scale, the long multisegmented A2 flagellum, the 5 segmented inner A1 flagellum, the large Md palp with many plumose setae and the posterior median spine on the telson appear to be characteristic features of postlarva I of *P. stylifera*. The occurrence of a small endopod bud on the 5th pair of pelopods is a peculiar feature which has not been mentioned by the earlier workers.

Sometimes the last mysis substage moults into an intermediate stage, which has all the characteristics of the postlarva except for the fact that the appendages have fewer number of setae and may lack the posteromedian spine on the telson.

X

Larval development – Pattern of penaeid larval development and generic characters of the larvae of the genera *Penaeus*, *Metapenaeus* and *Parapenaeopsis*

M. S. Muthu
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The general pattern of penaeid larval development is discussed and the diagnostic characters of the nauplius, protozoea, mysis and postlarva I belonging to the genera *Penaeus*, *Metapenaeus* and *Parapenaeopsis* are described and illustrated. Inter-specific differences among the larvae belonging to the same genus are not clear.

Apart from the 8 species of prawns, *Penaeus monodon*, *P. indicus*, *P. semisulcatus*, *Metapenaeus dobsoni*, *M. affinis*, *M. monoceros*, *M. brevicornis* and *Parapenaeopsis*

stylifera whose larvae have been described in detail in this bulletin, the complete larval development of a number of species of penaeid prawns has been traced from eggs spawned in the laboratory in many parts of the world. The larval stages of *Penaeus Japonicus* (Hudinaga, 1942, *Japanese J. zool.*, 10 (2): 305-393[1]) *P. orientalis* (Oka, 1967, *Bull. Fac. Fish. Nagasaki Univ.*, 23: 71-87[2]), *P. latisulcatus* (Shokita, 1970, *Biol. Mag. Okinawa*, 6(8): 34-36[3]), and *Metapenaeus joyneri* (Lee and Lee, 1968, *Publ. Haewundae Marine Lab.* 1: 1-18[4]) from Japan, *Penaeus monodon* (Villaluz *et. al.*, 1969, *Philippine J.Sci.*, 98 (3-4): 205-233[5]) from Philippines, *Metapenaeus bennette* (Morris and Bennet; 1951, *Proc. Linn. Soc. N. S. W.* 76: 104-82[6]), *Penaeus esculentus* (Fielder *et. al.* 1975, *Aust. J. mar. Freshw. Res.*, 26: 155-175[7]) from Australia, *Penaeus merguiensis* (Raje and Ranade, 1972, *J. Indian Fish. Ass.*, 2 (1&2): 1-16)[8] and *Metapenaeus monoceros* (Raje and Ranade, 1972 *J. Indian Fish. Ass.*, 2 (1 & 2): 30-46)[9] from India, *Penaeus trisulcatus, Parapenaeus longirostris* and *Sicyonia carinata*) Heldt, 1938, *Annl, Inst. Oceanogr. Monaco*, 18 (2): 31-206[10]), from the Mediterranean sea and *Penaeus setiferus* (Heegaard, 1953, *Publ. Inst. mar. Sci. Univ. Tex.*, 3 (1): 73–105[11]), *Penaeus duorarum* (Dobkin, 1961, *U. S. Fish. Wild. Ser. Fish. Bull.*, 61: 321-349[12]) *Penaeus aztecus* (Cook and Murphy, 1971, *U. S. Fish.Wildl. Ser. Fish. Bull.*, 69 (1): 223-239[13]), and *Sicyonia brevirostris* (Cook and Murphy, 1965, *Tulane Studies in Zoology*, 12 (4): 109-127[14]) from the Gulf of Mexico, have been described. A detailed study of the larval characters of the 8 Indian species presented in this Bulletin, and comparing them with the descriptions of the other species referred to above, has resulted in a clear understanding of the general pattern of development of the morphological features of the nauplius, protozoea, mysis and postlarval stages of the penaeid prawns and has brought to light certain generic characters by which the larvae belonging to the genera *Penaeus, Metapenaeus* and *Parapenaeopsis* could be identified. The earlier work of Cook (1966, *U. S.Fish. Wildl. Ser. Fish. Bull.*, 65 (2): (437-447)[15] on the generic characters of the penaeid larvae of the Gulf of Mexico region does not cover the typically Indo-Pacific genera. *Metapenaeus* and *Parapeneopsis* which are of great commercial importance in the latter region. This lacuna was partly filled by the work of Haq and Hassan (1975, *Pakistan J. zool.* 7 (2): 145-159[16]), who have described some of the generic characters of the larvae belonging to the genera *Penaeus, Metapenaeus* and *Parapenaeopsis* from Pakistan waters. However, during the present study we have found additional morphological features which appear to be characteristic of these three genera. Further we have found for the first time some characters by which even the nauplius stage of these three genera can be distinguished. The larvae of different species belonging to the same genus, however, are so similar that specific identification of the larvae is not possible, except for some stages of *Metapenaeus*. A summary of our observations on penaeid larval development is presented here.

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EGG STAGE

A very narrow perivitelline space (about 15 microns in width) appears to be characteristic of the eggs of all the species of *Penaeus* described so far. The eggs of *Metapenaeus* species (except *Metapenaeus dobsoni*) possess a narrow perivitelline space of 20 to 30 microns in width. The eggs of *M.dobsoni* are peculiar in having a very wide perivitelline space which is about 85 microns in width. The perivitelline space of the eggs of *Parapenaeopsis stylifera* is 60 microns wide. The diameter of the yolk mass was more or less the same (0.22 - 0.24 mm) in all the 8 species of penaeid eggs studied by us, the differences in the egg diameter being due to differences in the width of the perivitelline space which develops only after fertilization. The differences observed in the duration of the embryonic stage were due to differences in the rearing temperature; the eggs of *M. brevicornis* hatched out in 9 hours while the eggs of *P.indicus* took 16-17 hours to hatch out, the rearing temperature being 29.2 to 30.8° C in the former case and 24.4 to 26.8°C in the latter.

NAUPLIUS STAGE

The nauplii of all the penaeids studied passed through 6 nauplius substages which could be distinguished on the basis of the number of furcal setae as follows:-

Stage:	N I	N II	N III	N IV	N V	N VI
Furcal setae:	1+1	1+1	3+3	4+4	6+6	7+7

In N III the inner pair of furcal setae are very minute and ventrally placed and could be easily overlooked when viewed from the dorsal side. Similarly in N IV the outermost pair of setae is minute and placed a little dorsally and could be missed when viewed from the ventral side.

In N V the outermost pair is minute and placed a little dorsally on the lateral margin and could be missed when seen from the ventral side. This may account for the variation in the number of nauplius substages recognised by the earlier workers. While the first 4 nauplius substages are passed through rapidly (3 to 6 hours) the larvae linger for a longer time in N V (10 to 12 hours) and N VI (15 to 24 hours).

In N I the A1 bears terminally 2 long seta and a minute setal rudiment on the inner angle and a long lateral seta on the outer distal marle gin; this latter seta is actually dorsolateral in poisition; on the inner lateral margin there are 2 or 3 small setae which are actually ventrolateral in position; all the setae during this stage are non-plumose; they may have very short bristles which appear to be the developing setules. In N II the setae become plumose and the outer of the two long terminal setae and the outer distolateral seta are reduced in size and the minute setal rudiment develops into a short seta. In N III this latter seta becomes longer than the outer terminal seta and the outer distolateral seta becomes very thin and small. In N IV the inner terminal seta lengthens further and the thin outer distolateral seta disappears. In N V the inner terminal seta grows in length but is still shorter than the long middle terminal seta. In N VI 2 additional setae and a minute setal rudiment are added on outer distolateral margin. The 2 distolateral setae and the short outer terminal one appear to be actually aesthaetes. The A1 becomes indistinctly segmented in the proximal half in N VI.

In the A2 exopod also the pattern of development of the setae is similar in all the species. In N I there are 5 long setae along the inner and distal margin.

In N II the 4th seta from the proximal end acquires a characteristic bend distally and the seta is bifurcate beyond this bend in all the species observed during the present investigations. The bifurcate nature of this particular seta is retained in all the subsequent nauplius substages. The bifurcate seta was noted by Renfro and Cook (1963, *U. S. Fish wildl Ser. Fish. Bull.*, 63 (1): 165- 177)[17] in the later nauplius substages of *Xiphopenaeus kroyeri*, as a variation. But it is invariably present in the nauplius of all the species studied here. An additional seta of A2 exopod was noticed to be bifurcate as a variation but the 4th seta was always bifurcate. The significance of the bifurcate nature of this seta is not clear. Perhaps, it may have some function associated with swimming and floating of the nauplius. For every naupliar moult the number of setae on the exopod increases atleast by the addition of one setal rudiment to the outer distal end or the transformation of a setal rudiment into a seta. In N IV, V and VI a short proximal seta is added to inner margin. The A2 exopod becomes indistinctly segmented from N IV onwards.

In the A2 endopod also the pattern of development of the setae is similar in all the species. In N I the endopod bears 2 short inner lateral setae and 2 long terminal setae and a minute setal rudiment on inner terminal angle. The latter becomes larger in N II and becomes a short seta in N III. A 4th terminal seta is added in N VI. In N VI the distal of the 2 lateral setae becomes longer and a short seta may be added to the base of this seta.

Md has 3 long terminal setae on the exopod and endopod in all the nauplius substages in all the species. From N IV a basal swelling develops; in N VI this swelling is very prominent and the cutting teeth of Md can be seen developing inside it. In N VI the endopod becomes empty and transparent.

Rudiments of Mx1, Mx2, Mxp1 and Mxp2 first appear in N III under the cuticle and become free in N V and acquire rudimentary setae in N VI.

The relative length of the inner lateral setae on A1 and the distribution of the distolateral setae (aesthaetes) on the outer margin of A1 in N VI provide certain diagnostic characters for distinguishing the nauplius belonging to the genera *Penaeus, Metapenaeus* and *Parapenaeopsis*. The nauplii of the 3 genera could be characterised as follows:-

Penaeus: A1 (Fig. 1,a) has only two inner lateral setae in N I to N IV, the distal seta being very long, a minute proximal seta may be added in N V or N VI; the very long distal seta is characteristic of the genus. Of the 3 distolateral aesthaetes the most distal is terminal while the other 2 are subterminal, the middle one being equidistant from the terminal and proximal ones.

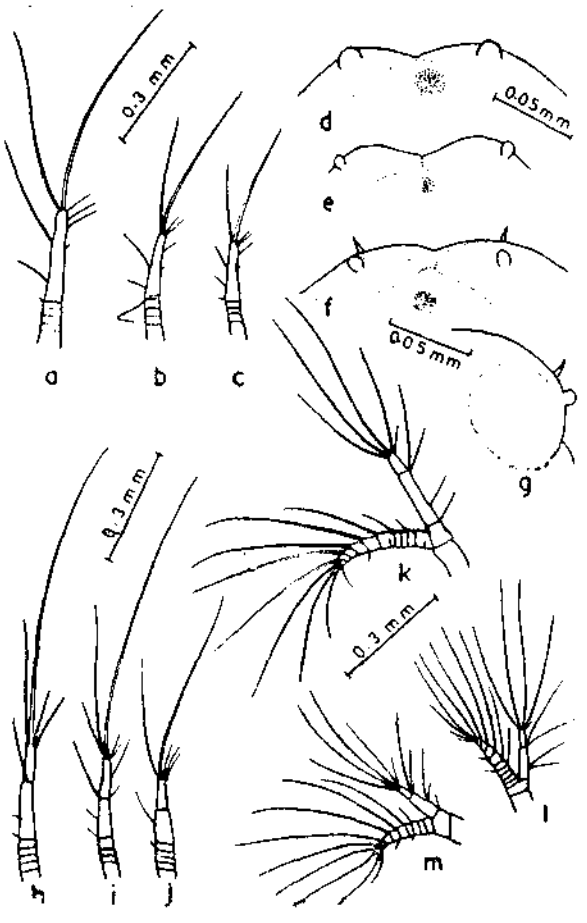

Fig. 1 A1 of Nauplius VI: a - *Penaeus;* b - *Parapenaeopsis;* C - *Metapenaeus*. Frontal organ (Ventral view) of protozoea I: d - *Penaeus;* e - *Parapenaeopsis;* f - *Metapenaeus;* g - lateral view of fronfal organ of *Metapenaeus*. A1 of protozoea I; h - *Peneus;* i - *Parapenaeopsis;* j - *Metapenaeus*, A2 of protozoea I: k - *Penaeus;* l - *Parapenaeopsis;* m - *Metapenaeus*.

Metapenaeus: A1 (Fig. 1, c) has 3 short inner lateral setae in all the 6 nauplius substages; the size decreases gradually from the distal to the proximal seta; there is no change in the relative length of these 3 setae fron N I to N VI. Out of the 3 aesthaetes one is terminal and 2 are subterminal and dorsolaterally placed; the middle one is closer to the terminal one than to the proximal one.

Parapenaeopsis: A1 (Fig:1,b) has 3 inner lateral setae in all the 6 nauplius substages. Up to N III, the setae are short, slightly decreasing in length from the distal to the proximal one. But from N IV to N VI the proximal seta becomes thin and greatly elongated. It is directed posterolaterally and is so long that it overlaps its fellow on the other side and is sharply bent in distal 1/3. Pearson (1939, *Bull. U.S. Bur. Fish* 49 (30): 1-73[18]) has shown a thin long proximal inner lateral seta on the A1 of the nauplius of *Trachypenaeus constrictus*. But it is directed anterolateraly and is not as long as in *Parapenaeopsis*. This condition may be characteristic of the genus *Trachypenaeus*, emphasising the close affinity of these 2 genera. Further, the long proximal inner lateral seta is shown in the illustration of the late nauplius substages of *Xiphopenaeus kroyeri* given by Renfro and Coock[17] . It is likely that *Xiphopenaeus* is also phylogenetically close to the general *Parapenaeopsis* and *Trachypenaeus*. This is also borne out by the similarity of the basic pattern of the petasma and thelycum of these 3 genera.

PROTOZOEA STAGE

All penaeid larvae studied pass through 3 distinct protozoea substages. The transition from one substage to the next is marked by abrupt morphological changes. Protozoea I is devoid of rostrum, the eyes are sessile beneath the carapace and the pereopod buds are absent; in protozoea II the rostrum and pereopod buds develop and the eyes become stalked; in protozoea III the first five abdominal segments develop posteromedlian dorsal spines, the 5th abdominal segment acquires a pair of posterolateral spines and the uropod buds are present. The intermoult growth of protozoea I, II and III first noticed by Hudinaga[1] in *penaeus japonicus* was observed in all the 8 species studied

here. Lee and Lee (1969, *publ. Mar. Lab. Pusan Fish.Coll.* 2 : 19-25)[19] have found that unlike the embryonic and nauplius stages, whose duration is dependant mainly on the rearing temperature, the duration of the protozoea stage is also greatly influenced by the quality of food offered to the larvae. This finding is confirmed by our present studies.

Cook[15] used the following criteria to differentiate the protozoea substages of the penaeid genera: (1) relative length of A1 and A2, (2) nature of cleft of telson, (3) setation of A2 endopod, (4) shape of frontal organ, (5) presence or absence of Mxp3 bud and (6) presence or absence of supraobital spines. Haq and Hassan[15] indicated that the number of segments in A1 and the number of setae on A2 exopod are also of generic importance. During the present study it was found that the following criteria are also useful for distinguishing the genera (1) the disposition of the setae on the caudal furcae, especially that of the outermost pair and the pair medial to the longest pair and (2) the segmentation and setation of the endopod of Mx1 and Mx2. On the basis of the above criteria the protozoea stages of the 3 genera *Penaeus*, *Metapenaeus* and *Parapenaeopsis* could be characterised as follows:

Penaeus: Frontal organs bluntly ronnded, not overhung by frontal horns (Fig.1,d). Rostrum long and ventrally bent in protozoea II and III. Supraorbitals bifid in protozoea II (Fig.3,d) and simple in protozoea III. Telson with a shallow wide cleft (Fig.3,a), the outermost lateral setae dorsally disposed, the pair of setae immediately inner to the longest pair of setae, sigmoid in protozoea I. Protozoea III has 8 pairs of telsonic setae (Fig.3,m). In protozoea III posterolateral spines on 6th abdominal segment prominent. A1 and A2 almost equal in length; basal segment of A1 with 5 subsegments in protozoea I and II (Fig.1,h), A1 of Protozoea III 3 segmented (Fig.3,g), A2 endopod has 1+1+2 lateral setae and 5 terminal setae, one short and 4 long, exopod with 11 setae on inner and distal margin (Fig. 1,k). Endopod of Mx1 with 3 segments, the distal one with 5 terminal setae, the middle and basal segments with 2 and 3 inner lateral setae respectively (Fig.2,a). The endopod of Mx2 4 segmented, the distal segment with 3 terminal setae and the other 3 segments each with 2

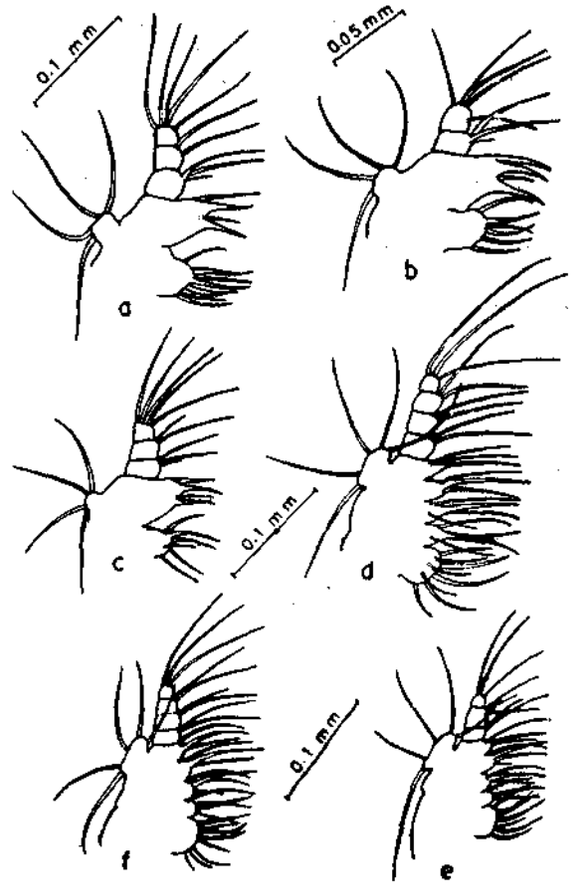

Fig. 2 Mx1 of protozoea I: a - *Penaeus;* b - *Parapenaeopsis;* c - *Metapenaeus.* Mx2 of protozoea I: d *Penaeus;* e - *Parapenaeopsis;* f - *Matapenaeus.*

long setae on inner margin (Fig. 2,d). Mxp3 buds absent in protozoea I and II and present in protozoea III with 2 setae on exopod bud alone (Fig.3,j). The protozoea substages of *Penaeus indicus, P. monodon* and *P. semisulcatus* are so similar that they cannot be distinguished from each other.

Metapenaeus: Rounded frontal organs usually overhung by pointed spine (Fig. 1,f,g); rostrum in protozoea II and III fairly long and ventrally bent. One pair of supraorbital spines present in protozoea II and III, those in protozoea II simple (Fig.3,f). Caudal furcae short and broad, with shallow and moderate cleft, outermost pair of furcal setae slightly ventrally disposed (Fig.3,c); the pair inner to the longest

pair not sigmoid; only 7 pairs of setae in protozoea III (Fig.3,o) In protozoea III posterolateral spines on 6th abdominal segment minute. A1 and A2 almost equal in length. Basal segment of A1 with 5 subsegments in protozoea I and II (Fig.1,j), A1 of protozoea III 3 segmented (Fig.3,i). A2 endopod with 1+2+3 lateral setae and 5 terminal setae, 4 long and one medium; exopod with 10 setae on inner and distal margin (Fig.1,m). Endopod of Mx1 3 segmented, the distal segment with 5 terminal setae and the middle and basal segments with 2 and 3 inner lateral setae respectively (Fig 2,c). Endopod of Mx2 with 3 distinct segments, the large middle segment divided into 2 by indistinct segmentation, the distal segment with 3 terminal setae and the rest with 2 lateral setae each (Fig.2,f) Biramous bud of Mxp3 present even in protozoea I; in protozoea III this appendage bears 3 setae on exopod and 2 setae on endopod (Fig.3,l).

The protozoea I of *M. monoceros* differs from that of the other 3 species of *Metapenaeus* in having very minute frontal horns, smaller than the frontal organs; the frontal horns are prominent in *M. dobsoni*, *M. brevicornis* and *M. affinis*. Protozoea II and III of *M. dobsoni* and *M. brevicornis* are devoid of rostral platforms, while in *M. affinis*. and *M. monoceros* the rostral platform is well developed, with rounded anterolateral corners in the former and sharp spine-like anterolateral corners in the latter.

Parapenaeopsis : Frontal organs of protozoea I rounded (Fig.1,e) not overhung by pointed spine. Rostrum short and straight, supraorbital spines absent in protozoea II and III (Fig.3,e). Posterolateral spines on 6th abdominal segment inconspicuous in protozoea III. Cleft in telson deep and wide, the caudal furcae narrow and long, the outermost pair of setae laterlly disposed and separated from the penultimate pair by a wide gap, the pair of setae immediately medial to the longest pair not sigmoid (Fig 3,b). A1 distinctly longer than A2. Basal segment of A1 with 4 subsegments in protozoea I (Fig 1,i) and 3 subsegments in protozoea II, A1 of protozoea III 4 segmented (Fig.3,h). Lateral setae on A2 endopod 2 + 2, terminally with 4 long plumose setae and 1 short hair-like seta, exopod with 10 setae along inner and distal margin (Fig.1,l). Mx1 with 2 segmented endopod (Fig.2,b), the distal segment with 4 terminal setae and one lateral seta in the middle, the basal segment with 3 lateral setae. Mx2 (Fig.2,e) with 3 segmented endopod, distal segment with 3 terminal setae, the middle segment with 2 distolateral setae and one lateral seta springing from the middle of the segment and the basal segment with 2 lateral setae. Biramous bud of Mxp3 present even in protozoea I, in protozoea III this appendage bears 3 setae on the exopod and 2 setae on the endopod (Fig.3,k).

MYSIS STAGE

Unlike the protozoea substages, the transition from one mysis substage to the next appears to be a very gradual one marked only by the increase in body length and the increase in number of setae in many of the appendages. The number of mysis substages appears to vary in the different penaeid genera. Only 3 mysis substages have been observed in all the species of the genus *Penaeus* studied so far(Heldt[10] , Hudinaga[1] , Cook and Murphy [13] , Villaluz[5], Raje and Ranade[8], Fielder *et. al*[7], Silas *et. al., Bulletin CMFRI* No.28 [20] , Muthu *et. al., Bulletin CMFRI* No.28[21] , Devarajan *et. al, Bulletin CMFRI* No.28[22]). But 4 to 6 mysis substages for species of the genus *Metapenaeus* (Morris and Bennet[6]; Raje and Ranade[9]; Muthu, *et. al.* 1979 *M. dobsoni, Bulletin CMFRI* No.28[23]; Muthu *et. al.* 1979, *M. affinis, Bulletin CMFRI* No.28[24] Mohamed *et. al*, 1979 *M. monoceros Bulletin CMFRI* No.28[25]), 7 substages for *Parapenaeopsis* (Muthu *et al*; 1979, *Parapenaeoposis stylifera Bulletin CMFRI* No.28[26]), 4 substages for *Sicyonia* (Cook and Murphy[14]), and 14 substages for *Parapenaeus* (Heldt[10]) have been described.

In the laboratory cultures where the larvae are grown under crowded conditions, the lack of suitable and sufficient food for the larvae and the accumulation of metabolites in the medium may affect the moulting frequency of the larvae and thus lead to variability in the number of substages. Broad (1957, *Biol. Bull.* 112: 144-161[27]; 1957. *Biol Bull.* 112:162-170[28]) found that the number of zoea stages and the duration of the larval period of the caridean prawn *Palaemonetes Pugio* and *P.vulgaris* increased when the larvae were reared on unsuitable

diets. Broad [27] opined that since trophic conditions may vary in nature during the breeding season of the species, a possible response to suboptimal conditions might be prolonged larval life with a greater number of larval intermoults. Pike and Williamson (1964, *Crustaceana*:6:265-284[29]) also found that under certain conditions larvae of *Pandalus motagui* reared in the laboratory passed through several addifional zoea substages before moulting to megalopa. To what extent the environmental factors contribute to the variability of the number of mysis substages in penaeids is not known at present. In the case of *Sicyonia brevirostris* Cook and Murphy[14] found that the number of substages present in a large volume of planktonic material from the sea was the same as that found among laboratory reared larvae. One of us (M.S.M.) has also recorded 6 mysis substages of *Parapenaeopsis stylifera* from the inshore plankton at Madras; this is in close agreement with the 7 substages observed by us in the mass culture of larvae of *P. stylifera* at the Narakkal Prawn Culture Laboratory. Such observations suggest that the increased number of mysis substages found by us during the laboratory rearing of *Metapenaeus* and *Parapenaeopsis* species may be normal for the respective species even in the natural environment.

It is quite likely that the mysis substages of penaeid prawns, like the furcilia stages of euphausids with which they have been equated by Gurney (1943, *Ray. Soc. Lond. Monogr* 129, 1-306)[30], exhibit the phenomena of "dominant stages" and "skipping of stages". Silas and Matthew (1977, *Proc. Symposium on Warmwater Zooplankton, Special publ,* NIO, Goa, 171-182[31]) have reviewed these concepts as far as euphausids are concerned and it appears possible that they are applicable to penaeid mysis substages as well.

The flexibility in the development of the mysis substages of penaeids is interesting from another point of view. The ability of some species to moult into a number of mysis substages may have survival value. We found that while rearing the mysis larvae of *P.indicus, P.monodon* and *P.semisulcatus,* which had only 3 mysis substages, if the conditions were not optimal, mass mortalities were more frequent, than in the case of the other species such as *M. dobsoni, M.affinis, M.monoceros* and *P.stylifera* which had 5 to 7 mysis substages. Even in nature when the conditions are unfavourable the larvae of these latter species may linger for a longer time in the plankton by moulting into these 5 to 7 mysis substages and thus gain time till the conditions improve.

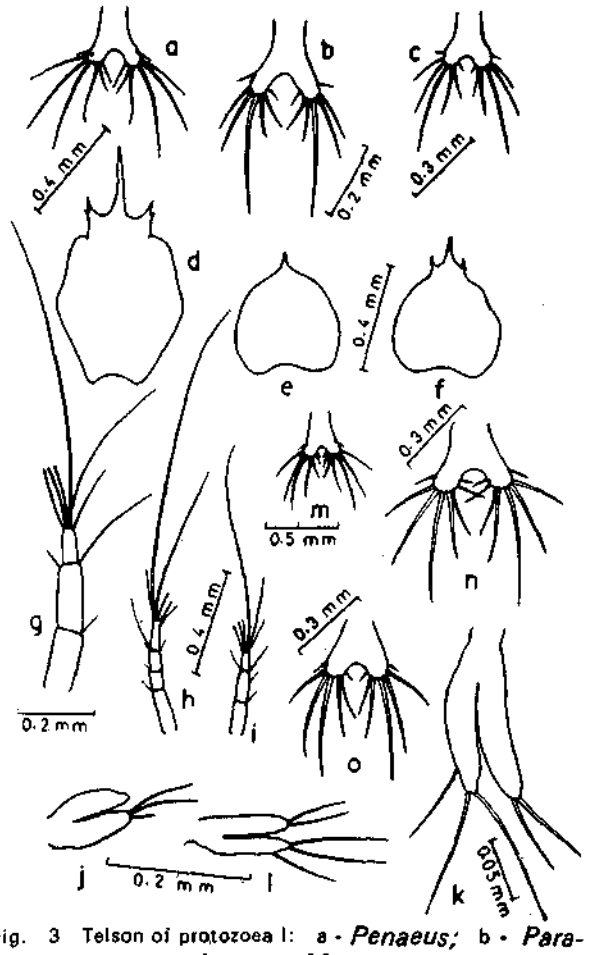

Fig. 3 Telson of protozoea I: a - *Penaeus;* b - *Parapenaeopsis;* c - *Metapenaeus.* Carapace of protozoea II: d - *Penaeus;* e - *Parapenaeopsis;* f - *Metapenaeus.* A1 of protozoea III: g - *Penaeus;* h - *Parapenaeopsis;* i - *Metapenaeus;.* Mxp3 of protozoea III. j - *Penaeus;* k - *Parapenaeopsis;* l - *Metapenaeus.* Telson of protozea III: m - *Penaeus;* n - *Parapenaeopsis;* o - *Metapenaeus.*

Mysis I in all the 3 genera viz *Penaeus, Metapenaeus* and *Parapenaeopsis* appears to possess the following features which are not shared by the succeeding substages. (1) the scaphocerite has an outer distolateral seta instead of a spine as in the subsequent substages, (2) Mx1 retains the exopod with 4 feathery setae, (3) Mxp2 has a 4 segmented endopod with 5 terminal setae, in subsequent stages the endopod is 5 segmented and there are

6 terminal setae on distal segment, (4) the protopod of A2 does not bear an anteroventral spine, which is present from mysis II onwards.

Cook[19] used the spination of the carapace and abdomen to identify the mysis stage of the different genera. Haq and Hassen[16] found that the segmentation of the flagellar rudiments of A1 and the segmentation of A2 flagellum are also useful for this purpose. During the present study the following additonal criteria were recognised, (1) Mx1 and Mx2 retain the peculiarities that were noted in the protozoea stage. (2) In Mxp1 the setation of the exopod is constant from the 1st to the last mysis substage and appears to be characteristic for each genus. (3) the number of setae on the exopod and endopod of the pereopods also provide useful criteria for distinguishing the genera. (4) the outer distolateral spine on the exopod of the uropod is also peculiar to each genus. Although Paulinose (1977, *Proc. Symposium of Warmwater Zooplankton, Special publ.* NIO Goa[12]) felt that the structure of the asymmetrical Md during the mysis stage could be used to distinguish some genera, a careful examination of the Md during the present study did not reveal any consistent difference in the 3 genera studied by us.

The mysis stage of *Penaeus, Metapenaeus* and *Parapenaeopsis* could be distinguished on the basis of the following diagnostic characters.

Penaeus: Carapace with prominent supraorbital (Fig.4,a) pterygostomial and hepatic spines, antennal spine absent. Abdominal segments 3 to 6 with dorsomedian spines, 5th and 6th segments each with prominent posterolateral spines, the dorsomedian spines on segments 3-5 are variable in size and may be absent on segments 3 and 4 in mysis II and III. Mx1 with 3 segmented endopod with 5 terminal setae on distal segment, 2 lateral setae on middle segment and 3 lateral setae on basal segment, Mx2 with a 4 segmented endopod, with 3 terminal setae on distal segment and 2 lateral setae in each of the 3 other segments. Mxp1 (Fig.4,g) with 10 - 12 setae on exopod. Endopod of pereopods (Fig.5,a,d) with short lateral setae exopod of pereopods with 2+4+2 or 1+4+2 distal setae. Uropod with outer margin of exopod (Fig.5,g) produced into a very prominent distolateral fixed spine beyond which the fringing setae are arranged, the outermost member of this series of setae is shorter than the distolateral spine and is nonplumose. Only 3 mysis substages; mysis I with minute pleopod buds; in mysis II the pleopod buds are well developed with a constriction in the middle; in mysis III the pleopods become clearly 2 segmented. The mysis substages of *P. Indicus, P. monodon* and *P. semisulcatus* are so similar that they cannot be distinguished from one another.

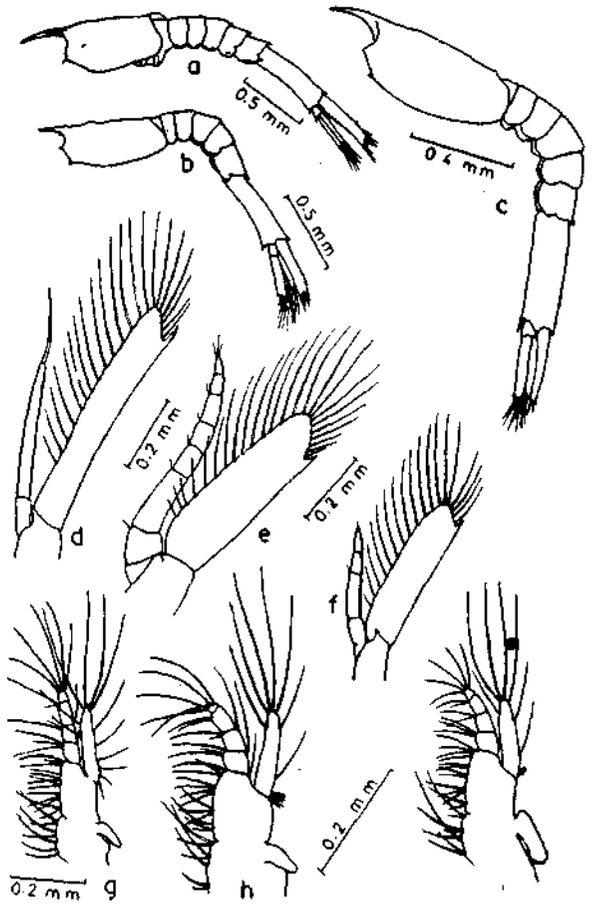

Fig. 4 Lateral view of carapace and abdomen of Mysis 1: a - *Penaeus;* b - *Parapenaeopsis;* c - *Metapenaeus.* A2 of last Mysis: d - *Penaeus;* e - *Parapenaeopsis;* f - *Metapenaeus.*

Metapenaeus: Carapace without supraorbital spine (Fig.4,c), but with antennal and pterygostomial spines, hepatic spines usually absent in mysis I but appear in later substages. Only abdominal segments 5 and 6 with dorsomedian spines; no lateral spines on any segment. Mx1 with 5 terminal setae on distal segment, 2 on middle segment and 3 on basal

segment. Mx2 endopod with 4 indistinct segments bearing 3 terminal setae on distal segment and 2 lateral setae on each of the other 3 segments. Mxp1 with 7 setae on exopod and 2-3 small hairs proximal to the outermost seta (Fig.4,i). P1-P5 with a long outer lateral seta on endopod from mysis II onwards, exopod of P1-P5 with 2+4+2 distal setae (Fig.5,c and f). On exopod of uropod the distolateral spine which is a continuation of the outer margin is absent in mysis I and is very small in subsequent stages, being shorter than the outermost movable non-plumose seta (Fig.5,*i*). May have up to 6 mysis substages.

Mysis I of *M. brevicornis* can be distinguished from that of the other 3 species of *Metapenaeus* by the presence of distinct though small supraorbital spines on the carapace. Mysis I of *M. dobsoni* has a minute pair of supraorbital spines on the anterior border of carapace, the dorsomedian spine on the fifth abdominal segment is minute. In *M. affinis* and *M. monoceros* the supraorbital spines are totally absent in mysis I and the dorsomedian sipne on 5th abdominal segment is large and well developed.

Parapenaeopsis: Carapace with small supraorbital spine at least in mysis I; hepatic spine absent in all mysis stages; antennal and pterygostomial spines present (Fig.4,b). Abdominal segments 5 and 6 with dorsomedian spines; mysis I may have a vestigial posterolateral spine in the lower half of the 5th abdominal segment; no lateral spines on 6th abdominal segment. Mx1 with short and stumpy 2 segmented endopod with 4 terminal setae and one lateral seta on distal segment and 3 lateral setae on basal segment. Mx2 with short and stumpy 3 segmented endopod with 3 terminal setae on distal segment and one lateral and 2 distolateral seta on middle segment and 2 distolateral setae on basal segment. Mxp1 with 7 setae on exopod and a cluster of hair like setules proximal to the outermost seta (Fig.4,h). P1-P5 with a very long outer lateral seta on endopod from mysis I onwards (Fig.5,b,e), exopod setae increasing in number from 3+4+3 in mysis I to 6+4+6 in last mysis substage. Exopod of uropod lacks the fixed distolateral spine in all mysis substages (Fig.5,h), the outermost member of the fringing setae on the exopod is nonplumose. May have 7 or more mysis substages.

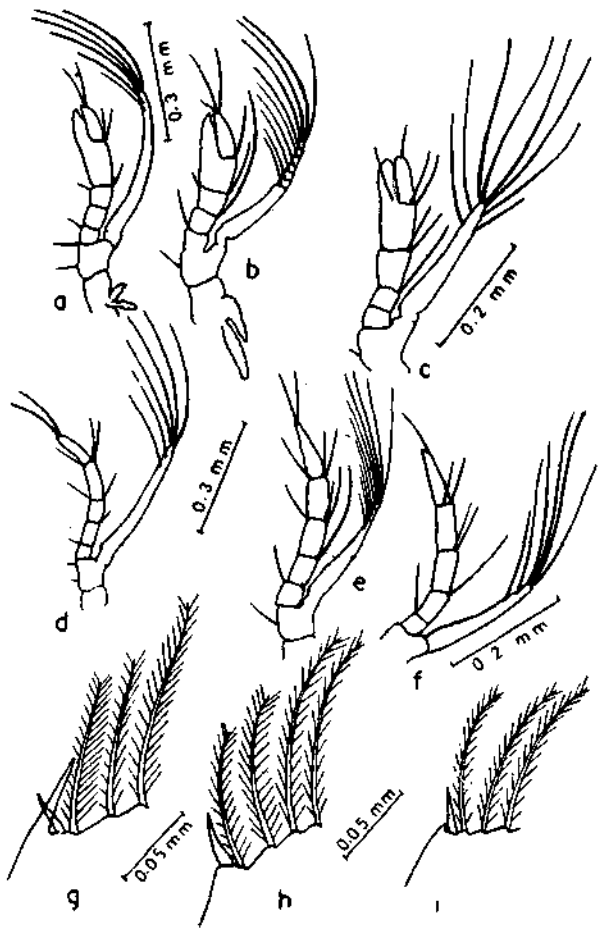

Fig. 5 P1 of last Mysis: a - *Penaeus;* b - *Parapenaeopsis;* c - *Metapenaeus* P5 of last Mysis: d - *Penaeus;* e - *Parapenaeopsis;* f - *Metapenaeus.* Outer distal margin of exopod of uropod of last Mysis: g - *Penaeus;* h - *Parapenaeopsis;* i - *Metapenaeus.*

The mysis substages of *Trachypenaeus fulvus* described by Kirkegaard (1969, *Fish. notes Dept. of Harbour and Marine* Queensland,. 3(1): 15-25[33]) from the plankton appear to belong to some species of *Parapenaeopsis* due to the following reasons: (1) in the mysis substages the endopod of Mx1 has 4 terminal setae on distal segment and 1 seta on middle segment, (2) the Mx2 in the mysis stage has an endopod described as typical of *Parapenaeopsis* in the above paragraph.

POSTLARVAL STAGE

Since the number of postlarval stages appears to be very large (about 20) and we cannot say when the postlarval stage ends and the juvenile stage begins, the present discussion is confined to the early (first 1 or 2) postlarval

stage. When the last mysis metamorphoses into postlarva I the following changes take place; (1) The pleopods acquire plumose setae for swimming, (2) the exopods of Mxp2 and Mxp3 and P1-P5 lose the plumose setae and become shrunken (3) the endopods of Mx1, Mx2 and Mxp1 become highly reduced (4) the free standing teeth between the incisor and molar processes of the Md are replaced by a sharp cutting edge, the Md palp becomes segmented and setose (5) endopod of Mxp2 becomes recurved and (6) the chelae on P1 to P3 become functional and the long plumose setae on the endopods are lost. But during artificial propagation, the last mysis may moult into 1 or 2 intermediate substages which have setose on pleopods but retain many of the characters of the mysis stage such as the free standing teeth in Md and plumose exopods of Mxp2, Mxp3 and P1 to P5.

The spination of the carapace, abdominal segments and telson proved useful in the generic identification of the early postlarvae. The diagnostic features are given below:

Penaeus: The postlarvae are long and slender. Rostrum long with 1 or 2 dorsal spines, supraorbital and hepatic spines present on carapace, posterodorsal and posterolateral spines present on 5th and 6th abdominal segments (Fig.6,a). Telson with 8 pairs of setae. Scaphocerite long and narrow, broader anteriorly than proximally (Fig.6,g); A2 flagellum shorter than scaphocerite. A1 flagella 2-3 segmented (Fig.6.d) Md palp cylindrical with distal segment smaller than and of same width as, proximal segment (Fig. 7,a).

The postlarva I of *P. indicus, P. monodon* and *P. semisulcatus* are morphologically alike.

Metapenaeus: Postlarvae small, rostrum short with 2 dorsal spines + 1 epigastric spine (Fig.6,c). Hepatic spine present but no supraorbital spine. Dorsal spine present only on 6th abdominal segment. no lateral spines on any abdominal segment: Telson with 7 pairs of setae. Scaphocerite uniformly broad in distal and proximal halves (Fig.6.i), A1 flagella 2 segmented (Fig.6,f), Md palp club shaped, distal segment broader than proximal (Fig.7,c). The blunt rostral tip of postlarva I is characteristic

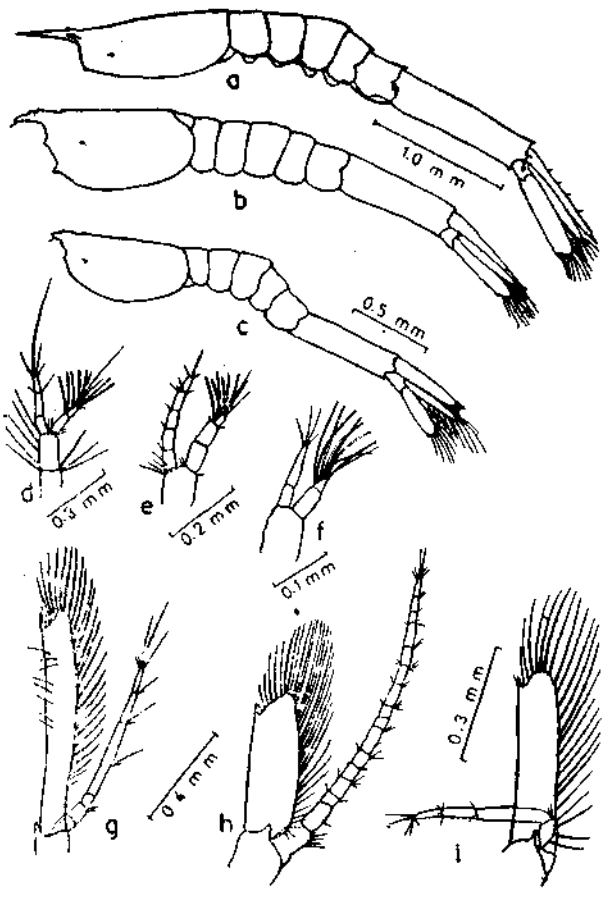

Fig. 6 Lateral view of carapace and abdomen of postlarva - I: a - *Penaeus;* b - *Parapenaeopsis;* c - *Metapenaeus.* A1 Flagella of postlarva I; d - *Penaeus;* e - *Parapenaeopsis;* f - *Metapenaeus.* A2 of postlarva I: g - *Penaeus;* h - *Parapenaeopsis;* i - *Metapenaeus.*

of *M. dobsoni;* the rostral tip is sharply pointed in *M. affinis* and *M. monoceros.*

Parapenaeopsis: Postlarvae stout. Rostrum short and curved (Fig.6,b), tip produced into a blunt tooth from which 2 long ventral plumose setae arise. 2-3 rostral spines + 1 epigastric spine. Hepatic spine present. Supraorbital spine absent. No dorsal or lateral spines on 1-5 abdominal segments, dorsal spine present on 6th abdominal segment. Telson with 8 pairs of setae and a posteromedian spine. Scaphocerite short and broad (Fig.6,h), broader proximally than anteriorly; A2 flagellum longer than scaphocerite with more than 10 segments. A1 flagella 3-5 segmented (Fig.6,e). Md palp (Fig.7,b) with a large oval distal segment and a smaller triangular proximal segment.

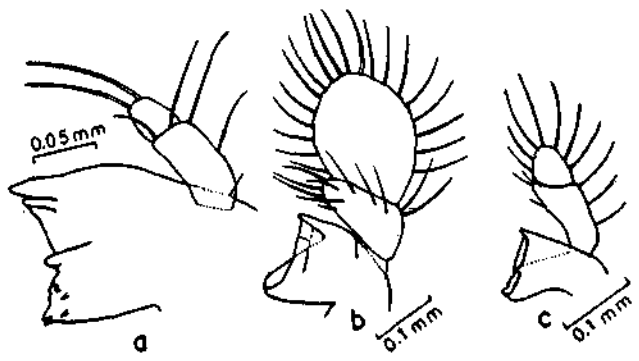

Fig. 7 Md. of postlarva I: a - *Penaeus;* b - *Parapenaeopsis;* c - *Metapenaeus.*

A generic key for the various larval stages is given below:

NAUPLIUS

1 a. The proximal inner lateral seta of A1 longer than the 2 anterior ones and filamentous in N IV to N VI..... *Parapenaeopsis*

1 b. The proximal inner lateral seta of A1 shorter than the 2 anterior ones in N IV to N VI 2

2 a. The anterior most inner lateral seta in A1 very long; the posterior most inner lateral seta absent or rudimentary in N I to N III. In the N VI the 3 aesthaetes on the outer distal margin of A1 equally spaced i. e. the middle one is equidistant from the distal and proximal ones..... .... *Penaeus*

2 b. The size of the 3 inner lateral setae on A1 decreases gradually from the anterior to the posterior one. In N VI the 3 aesthaetes on the outer distal margin of A1 not equally spaced, the 2 anterior ones closer to each other than to the posterior one..... *Metapenaeus*

PROTOZOEA I

1 a. A2 exopod with 11 setae along inner and distal margin, endopod with 1+1+2 lateral setae; outermost furcal seta dorsally disposed .....*Penaeus*

1. b. A2 exopod with 10 setae along inner and distal margin, endopod not with 1+1+2 lateral setae. Outermost furcal seta ventrally or laterally disposed.....2

2. a. A2 endopod with 1+2+3 lateral setae, Frontal horns usually present above frontal organs. Caudal furcae separated by shallow semicricular space, outermost furcal seta slightly ventrally disposed ..... *Metapenaeus*

2. b. A2 endopod with 2+2 lateral setae. No frontal horns above the frontal organs, caudal furcae separated by deep $\wedge$ shaped space; outermost furcal seta laterally disposed and widely separated from the penultimate outer seta .. . *Parapenaeopsis*

PROTOZOEA II

1. a. Supraorbital spines absent..... *Parapenaeopsis*

1.b. Supraorbital spines present..... 2

2.a. Supraorbital spines bifid .....*Penaeus*

2.b. Supraorbital spines simple...*Metapenaeus*

PROTOZOEA III

1.a. Telson with 7+7 furcal setae ..... *Metapenaeus*

1.b. Telson with 8+8 furcal setae 2

2.a. A1 4 segmented, supraorbital spine absent .... *Parapenaeopsis*

2. b. A1 3 segmented, supraorbital spine present .... *Penaeus*

MYSIS STAGE

1. a. 5th abdominal segment with a pair of posterolateral spines. Dorsal spines present on 4th, 5th and 6th abdominal segments; sometimes on 3rd segment also .... *Penaeus*

1. b. 5th abdominal segment devoid of posterolateral spines. Dorsal spines present only on 5th and 6th abdominal segment..... 2

2. a. Telson with 7+7 spines. Hepatic spine present in later mysis substages. . ... *Metapenaeus*

2. b. Telson with 8+8 spines. Hepatic spine absent in all mysis substages..... ... *Parapenaeopsis*

EARLY POSTLARVAE (up to P2)

1. a. 5th abdominal segment with posterodorsal spine..... *Penaeus*

1. b. 5th abdominal segment without posterodorsal spine 2

2. a. Telson with 7 pairs of spines..... *Metapenaeus*

2. b. Telson with 8 pairs of spines on either side of a median spine .. *Parapenaeopsis*

REMARKS

It is likely that many of the characters noted under the various larval stages of each genus may have suprageneric significance especially in the nauplius and protozoea stages and when the detailed morphology of the larvae of more penaeid genera are worked out they may throw interesting light on the phylogenetic relationships of the various genera. The following features are likely to be of interest in this connection: (1) the setation of A1 and A2 in the nauplius stage, (2) the number of subsegments present in the basal segment of A1 in the protozoea stage, (3) the segmentation and setation of the endopods of Mx1 and Mx2 in the protozoea and mysis stages and (4) the setation of the exopod of Mxp1 in the mysis stage.

XI

Larval development — Specific identity of penaeid postlarvae found in brackishwater areas

M. S. Muthu

Chromatophore pattern on the tail fan has been found to be a reliable and easily observed criterion for the identification of postlarval penaeids found in the brackishwater regions. The distinguishing characters of the postlarvae of *Penaeus indicus*, *P. meguiensis*, *P. semisulcatus*, *P. monodon*, *P japonicus*, *Metapenaeus dobsoni*, *M. monoceros*, and *M. affinis* are given and illustrated.

The possibility of using the postlarval abundance in brackishwater areas to predict the subsequent abundance of adult prawns in the sea has been discussed by Baxter (1963, *Proc. Gulf. Caribb. Fish. Instt;* 15: 79-87[1]), Christmas *et.al.* 1966, *Gulf Res. Rep.* 2 (2): 177-212[2].), George (1967, *Indian. J. Fish.* 10 (A): 135-139[3]), Berry and Baxter (1969, *FAO Fish. Rep.* 57 (3): 775-798[4]), and Rao (1972, *Indian. J. Fish.* 19: 86-96[5]). For work of this nature the specific identity of the postlarvae is essential, especially in a multispecies fishery. This is also necessary for selective stocking in prawn culture operations.

Various criteria have been used by previous workers for the identification of the postlarval penaeids. Williams (1959, *Bull. Mar. Sci. Gulf. Caribb;* 9 (3): 281-290.[6]) found that the postlarvae of *Penaeus setiferus*, *P. duorarum* and *P. aztecus* could be distinguished on the basis of (a) the shape of A1 scale and (b) the extent of the rostrum and the extent of the pereopods in relation to the eye. Ringo and Zamoro (1968, *Bull. mar. Sci.*, 18: 471-476[7]) found that the presence of minute spines on the dorsal carina of the 6th abdominal segment in the postlarvae of *P. aztecus* and *P. duorarum* is a taxonomic character which could be used to separate them from the postlarvae of *P. setiferus* which lack these spines. Mohamed *et. al.* (1968, *FAO Fish, Rep.*, 57 (2): 487-503[8]) have described the first postlarval stage of *P. indicus*, *M. monoceros*, *M. affinis* and *Parapenaeopsis stylifera* and used the number of telsonic spine, number of rostral spines, presence or absence of long setae on the distal lateral aspect of the 6th abdominal segment, the presence or absence of posteromedian dorsal spine on the 5th and 6th abdominal segments and the general body colour as criteria for identifying them. Sub-

rahmanyam and Rao (1970, *Proc. Indo Pacific Fish. Coun*, 13th sess. Sec. II: 113-127[9]) used the number of chromatophores on the ventral side of the body (especially on the 6th abdominal segment) and on the antennular peduncle to identify the postlarvae of *P. indicus*, *P. monodon*, and *P. semisulcatus*. Prawirodihardjo *et. al.* (1975, *Bull. Shrimp cult. Res. Cent.* 1 (1): 19-26[10]) have used the pigmentation of the uropod and telson to distinguish between the postlarva of *P. monodon* and *P. semisulcatus*.

In trying to identify the postlarvae found in the brackishwaters around Madras, it was found that the chromatophore pattern on the tail fan provided a very reliable criterion for identifying the early postlarval stages. The chromatophores were visible even in material fixed in formalin for 15-20 days if the specimens were kept in dark place away from light. The pattern is more important than the colour or number of chromatophores. On the basis of the chromatophore pattern on the tail fan the eight species of postlarval penaeids viz. *Penaeus indicus, P. merguiensis, P. semisulcatus, P. monodon, P. japonicus, Metapenaeus dobsoni, M. monoceros* and *M. affinis* could be sorted out with ease, speed and certainty. A key for their identification based on the chromatophore pattern of the tail fan is given below. It is applicable to the early postlarval stages i, e., postlarvae with 4-6 dorsal rostral spines in the case of *Penaeus* species and postlarvae with 3 rostral spines in case of *Metapenaeus* species. In later stage postlarvae more chromatophores develop and may obscure the primary chromatophore pattern described here. In the present collection the early postlarvae belonging to the genus *Penaeus* were large in size being 7-13 mm in total length while those belonging to the genus *Metapenaeus* were 3-4 mm in length.

The author is grateful to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute, Cochin, for for his valuable suggestions and encouragement.

Key to the identification of early postlarval stages found in the brackishwaters.

1 a. Telson bears 8 pairs of spines on sides and distal margin..... 2

b. Telson bears 7 pairs of spines on sides and distal margin..... 6

2 a. Telson with chromatophores in distal half only..... .....*Penaeus indicus*

b. Telson with chromatophores from base to distal end 3

3 a. Outer rami of uropods without chromatophores 4

b. Outer and inner rami of uropods with chromatophores 5

4 a. Inner rami of uropods with a single chromatophore near base on medial aspect (usually hidden by telson)..... ..... *Penaeus japonicus*

b. Inner rami of uropods with 3-4 chromatophore in the middle region on medial aspect *Penaeus merguiensis*

5 a. Distal half of inner and outer rami of uropods with numerous chromatophores .....*Penaeus semisulcatus*

b. Inner and outer rami of uropods with a row of chromatophores along the medial margin .....*Penaeus monodon*

6 a. Chromatophores present on outerand inner rami of uropods..... 7

b. Chromatophores present on inner rami of uropods, outer rami colourless..... *Metapenaeus monoceros*

7 a. A single chromatophores at tip of each uropod ramus .... *Metapenaeus affinis*

b. A prominent chromatophore in the middle of each uropod ramus .....*Metapenaeus dobsoni*

More details regarding the chromatophore pattern and other characters useful for the identification of the postlarvae are given in Table I. The diagnostic characters are illustrated in Fig. 1 and 2. The rostrum of the postlarva is drawn to indicate the stage of the postlarvae illustrated. The identification of the postlarvae studied was confirmed by rearing them in the

TABLE 1 Distinguishing characters

	P. indicus (Fig. 1, a-d)	*P.merguiensis* (Fig.1,e-h)	*P. monodon* (Fig.1, i-l)
1. Chromatophores			
i Telson	present in distal half only	present from base to distal end	present from base to distal end
ii Inner uropod ramus	*may have a minute one, but usually absent	3 to 4 on median aspect	a row of chromatophores along median aspect
iii. Outer uropod ramus	*absent	absent	3 to 5 in the middle on median aspect
iv. 6th abdominal segment			
a. Anterolateral chromatophore.	present	present	absent
b. Ventral chromatophores	6	5 to 6 more prominent than in *P. indicus*	13 to 18
c. Dorsal chromatophores	absent	absent	absent
2. Colour of chromatophores in live specimens.	red	red	maroon
3. Posteromedian dorsal spines on 5th abdominal segment	absent after two rostral spine stage	present up to 5 rostral spine stage	absent after two rostral spine stage
4. Rostrum	reaches end of eye	reaches end of eye	reaches end of eye
5. Spinules on dorsal carina of 6th abdominal segment.	absent	absent	absent
6. Antennal spine on carapace	absent	absent	absent

of the postlarval penaeids

P. semisulcatus (Fig.2,a-d)	*P. Japonicus* (Fig.2,e-h)	*M. dobsoni* (Fig.2i-l)	*M. monoceros* (Fig.2'm-p)	*M. affinis* (Fig.1,m-p)
present from base to distal end	present from base to distal end	two prominent ones in the middle	present from base to distal end	present from base to distal end
numerous, on distal half only	one near base on median aspect	one prominent in the middle	2-3 present	one present at distal end
numerous on distal half only	absent	one prominent in the middle	absent	one present at distal end
present	absent	absent	present	present
9 to 10	10 to 11	single	4 to 5	2
absent	absent	usually absent	single	single
brown	crimson	brown	reddish brown	brown
present up to 4 rostral spine stage.	present up to 4 rostral spine stage	absent	absent	absent
long, surpasses end of eye	short, reaching only half length of eye	very short, blunt	very short, pointed	very short, pointed
absent	present all along length of carina	2 to 3 may be present near posterior end	1 to 2 may be present near posterior end	1 to 2 may be present near posterior end
absent	prominent	present	present	present

* The inner and outer uropods of the earlier postlarvae of *P. indicus* in the sea (up to 3 rostral spine stage) have chromatophores in the distal half. These chromatophores disappear in the postlarvae with 4 rostral spines i. e. the stage at which they normally enter the brackishwater regions.

laboratory to the juvenile stage when they could be positively identified. It may be mentioned here that the chromatophore patterns illustrated in this paper for *Metapenaeus dobsoni*, *M. affinis* and *M. monoceros* are also valid for the mysis stage of the respective species.

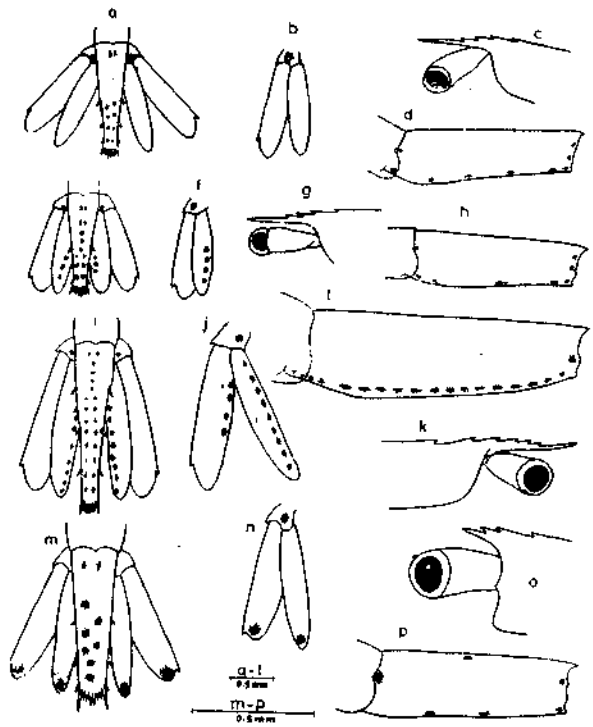

Fig. 1 a - d; *Penaeus indicus* (C. L. 1.70 mm); e - h, *Penaeus merguiensis* (C. L. 1.77 mm); i - l, *Penaeus monodon* (C. L. 2.73 mm ; m - p, *Metapenaeus affinis* (C. L. 1.0 mm); (a, e, i, m) tail fan; (b, f, j, n) left uropod; (c, g, k, o) anterior end of carapace; (d, h, l, p) 6th abdominal segment.

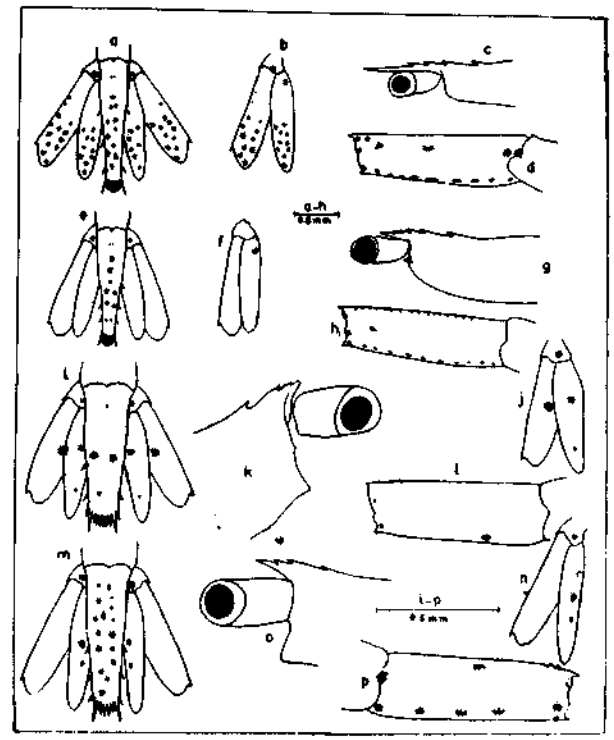

Fig. 2 a - d, *Penaeus semisulcatus* (C. L. 1.90 mm); e - h, *Penaeus japonicus* (C. L. 1.87 mm); i - l; *Metapenaeus dobsoni* (C. L. 0.89 mm); m - p, *Metapenaeus monoceros* (C. L. 1.01 mm); (a, e, i, m) tail fan; (b, f, j, n) left uropod; (c, g, k, o) anterior end of carapace; (d, h, l, p) 6th abdominal segment.